AD-A156 282 INSTALLATION RESTORATION PROGRAM PHASE II (STAGE 2-1) 1/3
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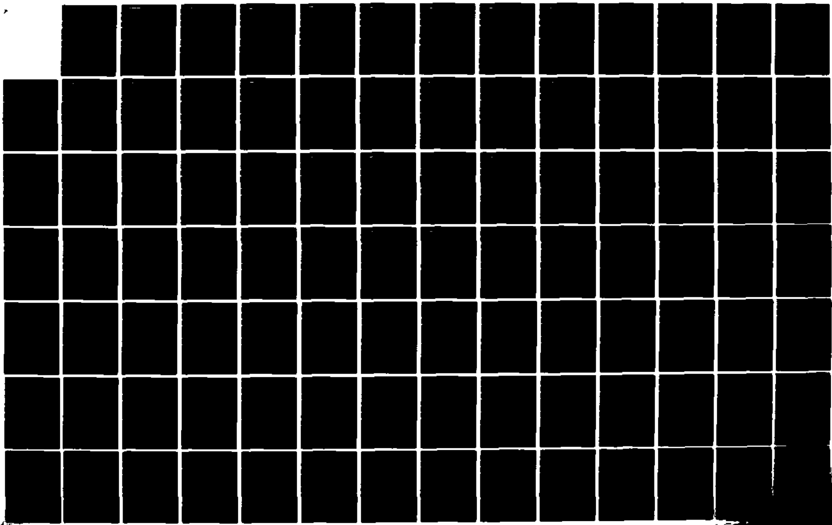

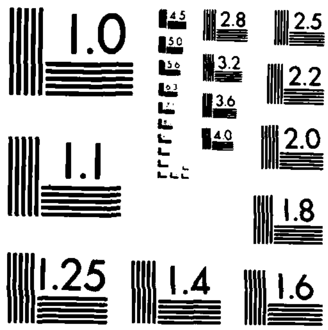

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INSTALLATION RESTORATION PROGRAM
PHASE II (Stage 2-1).

Volume 1
Final

McClellan AFB California
Air Force Logistics Command
Headquarters Air Force Logistics Command
Wright-Patterson AFB OH

May 1985

Prepared by:

Radian Corporation
Contract No.-F33615-83-D-4001, Order 16

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EXECUTIVE SUMMARY

BACKGROUND AND PURPOSE

The United States Air Force (USAF) is currently engaged in a program to identify and mitigate impacts resulting from past solid waste handling and disposal procedures at their facilities. This program is known as the Installation Restoration Program (IRP) and is composed of four phases. Phase I consists of Installation Assessments (Records Searches); Phase II is a confirmation of the existence or absence of contamination which is divided into Stage 1 (qualitative) and Stage 2 (quantitative) investigations; and Phase III is a Technology Base Development in which research and development of remedial action techniques will be conducted. In Phase IV, Operations, remedial action plans are to be designed and implemented.

In January 1984, Radian Corporation was directed to prepare a Presurvey Report to accomplish certain Phase II activities at McClellan Air Force Base (AFB) near Sacramento, California. McClellan AFB is located northeast of Sacramento, California as shown in Figure 1. The base includes 2,598 acres within the main installation boundaries. In addition to the 2,598 acre installation, McClellan AFB supports 978 acres of remote facilities as follows:

Davis Communications Annex	316 acres
Lincoln Communications Annex	356 acres
Capehart Family Housing Annex	217 acres
Camp Kohler Annex	35 acres
McClellan Storage Annex	52 acres
Sacramento River Dock Annex	1.7 acres
Middle Marker Annex	0.3 acres

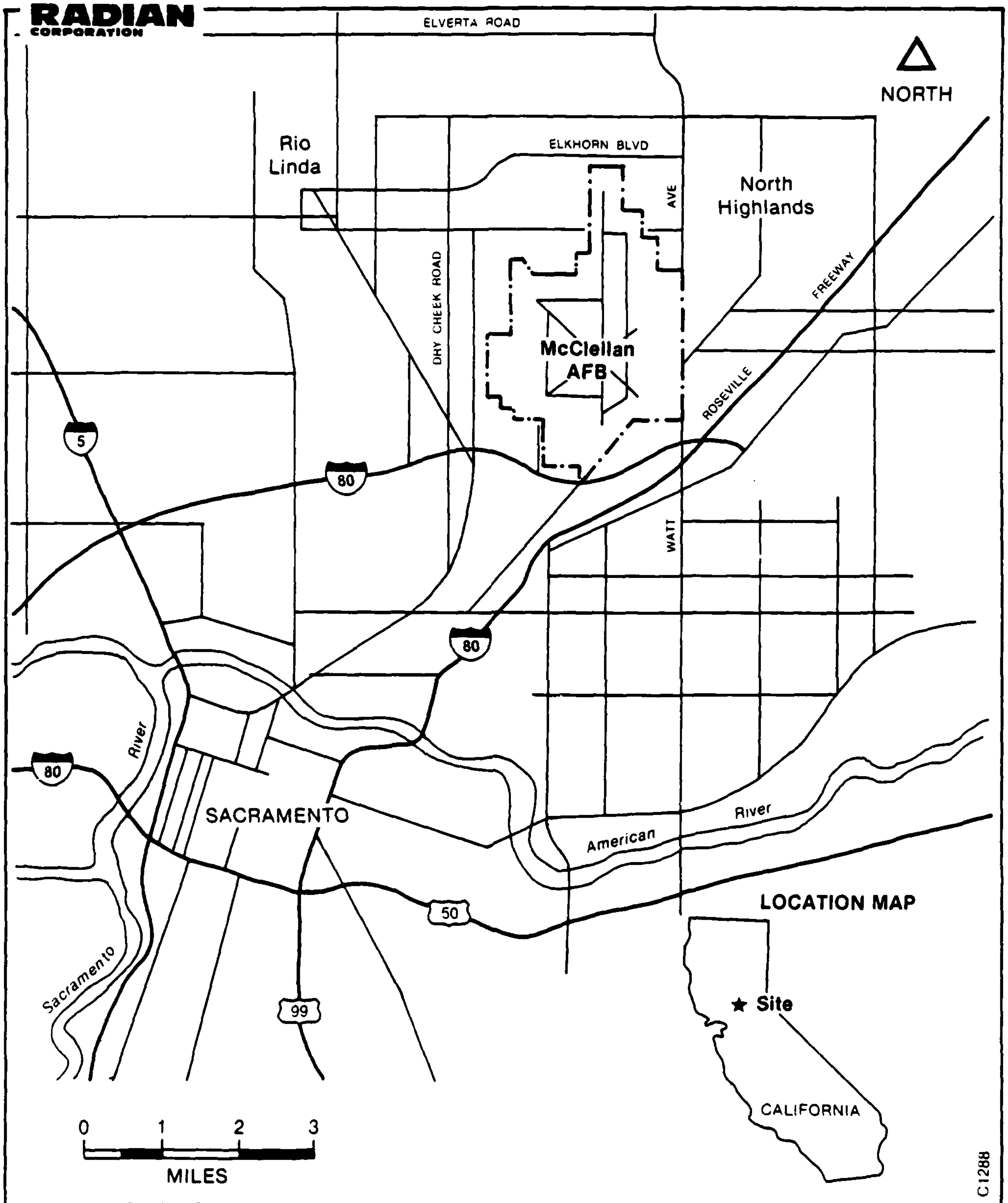

Figure 1 Location of McClellan Air Force Base

Activities identified in the Presurvey Report focused primarily on areas surrounding the base and were designated "Stage 2" activities. The Presurvey Report "Phase II Follow-On Monitoring Presurvey, Installation Restoration Program, McClellan AFB, California" was delivered to the United States Air Force Occupational and Environmental Health Laboratory (USAF/OEHL) on 10 February 1984. That report identified 10 tasks, divided into 30 subtasks, for the entire Phase II-Stage 2 program. The original tasks and subtasks are listed in Table 1.

AREAS OF INVESTIGATION

In the Phase I Records Search, 46 sites of potential environmental contamination were identified at McClellan AFB (CH_2M-Hill, 1981). These individual sites can be grouped into four geographic areas (Areas A, B, C, and D) which are shown in Figure 2 (Engineering-Science, 1983). Descriptions of the individual disposal and storage sites, including periods of operation, suspected materials disposed or stored, and estimated size are summarized in Table 2 (Engineering-Science, 1983).

FIELD PROGRAM

After submission of the original Presurvey Report, USAF/OEHL determined that the project should be accomplished in a phased approach. The first series of tasks were termed Phase II, Stage 2-1 and began 15 May 1984 under Delivery Order 16, contract F33615-83-D-4001. Table 3 lists the 13 tasks accomplished in Stage 2-1 and the corresponding "Actions" listed in the Delivery Order. The main objectives and approaches to accomplishing each of these tasks are summarized in the following paragraphs.

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TABLE 1 LISTING OF TASKS AND SUBTASKS PROPOSED IN ORIGINAL PRESURVEY REPORT FOR PHASE II--STAGE 2

Task 1	DATA REVIEW
1A	Program Implementation
1B	Historical Data Review
Task 2	WELL SURVEY
2A	Well Inventory
Task 3	GEOLOGIC CONDITIONS
3A	Geologic Evaluation Planning
3B	Reconnaissance Borings
3C	Aquifer Test Planning
3D	Aquifer Testing
3E	Data Evaluation
Task 4	MONITORING WELL SITING
4A	Monitor Well Planning
Task 5	WELL CONSTRUCTION
5A	Drilling Assessment
5B	Monitoring Well Installation
Task 6	SAMPLING EQUIPMENT
6A	Materials Assessment
6B	Sampling Design
Task 7	SAMPLING PROTOCOL
7A	Sampling Protocol
Task 8	SAMPLING/ANALYSIS
8A	Well Sampling
8B	Sample Analysis
8C	Training
Task 9	MODELING
9A	Data Evaluation
9B	Model Selection
9C	Model Implementation
9D	Data Reduction
9E	Transport Modeling
Task 10	REMEDIAL ACTIONS
10A	Criteria Development
10B	Identification & Screening
10C	Alternatives Development
10D	Alternatives Costing
10E	Environmental Assessment
10F	Cost Effectiveness Evaluation
10G	Recommendations

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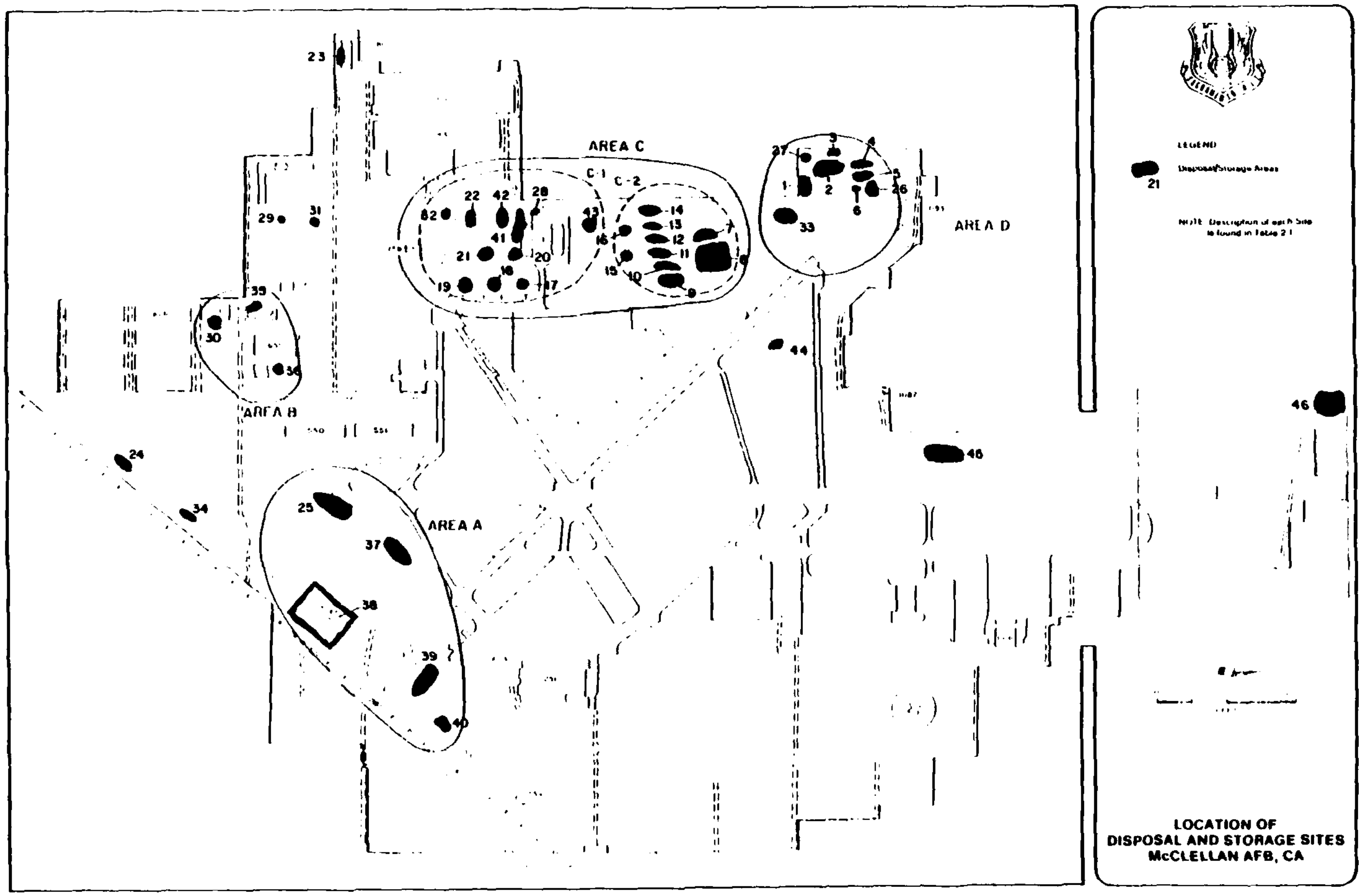

Figure 2 Location of Disposal Areas

(From Engineering-Science, 1983)

TABLE 2 DISPOSAL AND STORAGE SITES IDENTIFIED IN PHASE I, McCLELLAN AFB, CALIFORNIA

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
1	Buring/burial pit	1959–1962	Refuse/solid waste	310 ft x 190 ft
2	Sludge/oil pit Refuse burning/burial pit	1962–1979	Refuse/solid waste; undewatered industrial sludge; oil; waste solvents; TCE-contaminated wastes	300–400 ft x 50 ft x 30 ft deep
3	Sludge/burning/burial pit	1962–1965	Undewatered industrial sludge; oil	300–400 ft x 50 ft x 30 ft deep
4	Sludge/oil pit	1967–1981	Undewatered industrial sludge; oil; TCE-contaminated wastes	300–400 ft x 50 ft x 30 ft deep
5	Sludge/oil pit	1972–1978	Undewatered industrial sludge; oil; waste solvents; TCE-contaminated wastes	300–400 ft x 50 ft x 30 ft deep
6	Oil burn pit	1972–1978	Oil; fuel; solvents	125 ft x 125 ft
7	Sludge/oil pit	1966–1977	Undewatered industrial sludge; oil; TCE-contaminated wastes	300–400 ft x 50 ft x 30 ft deep
8	Sludge/burial pit	1974–1981	Dewatered industrial sludge; demolition debris; creek debris; paint chips and residues; sanitary sewage sludge (grit); TCE-contaminated wastes	400 ft x 40 ft x 30 ft deep
9	Burial pit	Pre–1949–1953	Ash and partially burned residue from Sites 22 and 31; dewatered industrial wastewater treatment plant sludge; Plating bath solutions and sludges (including lead, tin, antimony, and possibly	100–400 ft x 50 ft x 30 ft deep

(Continued)

TABLE 2 (Continued)

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
9 (Continued)			cadmium plating wastes; degreasing solvents and sludges; paint residues; fuels (probably including leaded) and oils; PCB liquids, solids, transformers, and electrical components; miscellaneous laboratory chemicals; cyanide wastes (drummed); low-level radioactive wastes (possibly); herbicide/pesticide containers	
10	Burial pit	1953–1955	Same as Site 9	Same as Site 9
11	Burial pit[2]	1955–1957	Same as Site 9	Same as Site 9
12	Burial pit[2]	1967–1969	Same as Site 9[3]	Same as Site 9
13	Burial pit[2]	1969–1971	Same as Site 9[3]	Same as Site 9
14	Burial pit	1971–1974	Same as Site 9	Same as Site 9
15	Sodium valve trench	1940–1950	Sodium valves from aircraft engines	15–20 ft x 2 ft x 6–9 ft deep
16	Sodium valve trench	1940–1950	Sodium valves from aircraft engines	15–20 ft x 2 ft x 6–9 ft deep
17	Burial pit	1957–1959	Same as Site 9	Same as Site 9
18	Burial pit	1957–1959	Same as Site 9	Same as Site 9
19	Burial pit	1957–1959	Same as Site 9	Same as Site 9

(Continued)

TABLE 2 (Continued)

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
20	Sludge/oil pit	1956–1957	Industrial wastewater treatment plant sludge; oil	250 ft x 190 ft
21	Sludge/oil pit	1956–1957	Industrial wastewater treatment plant sludge; oil	250 ft x 220 ft
22	Burning pit/teepee burner/burial pit	1946–1968	Refuse, ash and residue; oily wastes; waste solvents (including TCE in significant amounts; waste chemicals	100 ft x 400 ft x 50 ft
23	Burial pit	1966–1969[4]	No information available	125 ft x 280 ft
24	Burning/burial pit	1964–1969	Demolition debris; scrap material (lumber and paper)	310 ft x 160 ft
25	Burial pit	1940s & early 1950s	No information available	625 ft x 250 ft
26	Sludge pit	Early 1960s	Undewatered industrial sludge	300–400 ft x 50 ft x 30 ft deep
27	Sodium valve trench	Late 1940s & early 1950s	Sodium valves from aircraft engines	15–20 ft x 2 ft x 6–9 ft deep
28	Creek debris sludge pit	Pre-1972	Creek debris/sediments; industrial waste spills and discharges (probably)	160 ft x 250 ft
29	Civil Engineering reclamation yard, transformer storage area, and scrap material burner	1950s & 1960s	Drums; transformers (some with PCBs)	160 ft x 250 ft
	Generator burial pit	1974	Aircraft generators (approximately 50–60)	

(Continued)

TABLE 2 (Continued)

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
30	Surface disposal site	Late 1950s - present	TCE; freon; diethyl ether; low-level radioactive wash water	220 ft x 220 ft
31	Refuse incinerator/ ash burial	1963-1968	Refuse/solid waste; ash	160 ft x 250 ft
32	Radioactive/hazardous waste storage	Pre-1963-1975	Low-level radioactive waste containers	160 ft x 160 ft
33	Industrial sludge land-farm	1972[5]	Industrial waste treatment sludge	350 ft x 250 ft
34	Waste solvent storage tanks	1950-1953	Waste solvents (2 underground tanks)	310 ft x 125 ft
35	Scrap metal burial pit	World War II[6]	Scrap strapping steel	220 ft x 160 ft
36	Open storage area	1958-1980	Plating shop chemicals	125 ft x 190 ft
37	Burial pit	Early 1950s[7]	Refuse	500 ft x 250 ft
38	Engine repair shop; carbon remover, storage/ burial/sludge pits	1940s-mid 1960s	Carbon remover, including ethylene, dichloride/cresylic acid/soap emulsion mixture and 50-50 mixture of cresylic acid/orthodichlorobenzene (large quantities in above and below-ground tanks); contaminated carbon removal sludges from skimming ponds	875 ft x 595 ft
39	Burning/burial pit	Pre-1941-1946	Refuse/ash; all base wastes	625 ft x 160 ft

(Continued)

TABLE 2 (Continued)

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
40	Industrial sludge drying beds (8, unlined)	1955–1972; 1980	Industrial wastewater treatment plant sludges in 4 beds (probably with significant concentrations of VOCs)	250 ft x 190 ft
41	Burial pit	Mid-1940s	Demolition debris (probably)	560 ft x 190 ft
42	Oil storage/burning/burial pits (3 parallel burial pits and 2 burning pits)	Mid-1940s–1960s	Oil; waste fuel; waste solvents; refuse	190 ft x 310 ft
43	Burial pit	Mid-1940s	Demolition debris (probably)	220 ft x 250 ft
44	Hazardous waste storage area	1975–Present	No information available	500 ft x 150 ft
45	Paint burial pit	1950s	Latex-based(?)paint (approximately 200–300 55-gallon drums)	560 ft x 160 ft
46	Salvage yard operation (under previous owner)	Mid-1960s–1978[8]	No information available (identified PCB surface contamination; possible burial pit)	500 ft x 375 ft

Source: Engineering-Science, 1983

[1]Site locations are shown on Figure 2.9-1.
[2]Fire training is currently conducted in the vicinity of the site.
[3]Cyanide wastes were possibly removed from Site 12 or 13 during 1967-1971.
[4]Material was removed in 1970.
[5]Temporary (2-to-4 months).
[6]Material was removed in 1950.
[7]Material was removed in 1956.
[8]Material was removed in 1981.

TABLE 3 LISTING OF DELIVERY ORDER 16 ACTIONS AND CORRESPONDING TASKS FROM ORIGINAL PRESURVEY

Delivery Order 16 Actions	Original Presurvey Tasks	Task Numbers for This Report
Action 1 - Development of Data Base Management System	1A - Project Implementation	1
	1B - Historical Data Review	2
Action 2 - Comprehensive Well Survey	2A - Comprehensive Well Survey	3
Action 3 - Geologic Evaluation	3A - Geologic Evaluation Planning	4
	3B - Reconnaissance Borings	5
	3C - Aquifer Test Planning	6
Action 4 - Selection of Well Construction Technology	5A - Selection of Construction Technology	7
Action 5 - Well Sampling Equipment and Strategy	6A - Materials Investigation	8
	6B - System Design	9
	6C - Sampling Strategy	10
Action 6 - Contaminant Transport Modeling	9A - Hydrogeologic System Evaluation	11
	9B - Model Selection and Requisition	12
Action 7 - Off-Base Monitoring Well Selection	7A - Off-Base Monitoring Well Site Selection	13

Task 1 - Data Management

A database management system was developed to store, handle, and access the large data sets which were generated in other tasks. Both site-specific data and general information were compiled in hard-copy and computer databases.

Task 2 - Data Review

Radian collected and reviewed applicable information regarding the environmental setting at, and around McClellan AFB. Approximately 7,500 pages of information were reviewed, reduced, and entered into applicable databases.

Task 3 - Well Inventory

An area surrounding McClellan AFB, primarily west and southwest of the base, was investigated to determine the number, location, and usage of wells. A systematic canvassing, followed by a questionnaire mailout, was used to identify both active and abandoned wells in the area.

Task 4 - Geologic Investigation Planning

In order to more accurately define the geology, hydrology, and areas of contaminant impact, a geologic investigation was planned. The planning included the selection of a drilling/sampling method, implementation of subcontracts, and selection of drilling locations. The proposed drilling program for reconnaissance borings was presented to Air Force and agency personnel and subsequently modified at the request of the California Regional Water Quality Control Board.

Task 5 - Reconnaissance Borings

A total of 29 reconnaissance borings were drilled on and around McClellan AFB to a depth of approximately 200 feet. These borings were drilled to define local geologic conditions, identify and sample aquifers, and provide data for placement of monitoring wells. Ground-water samples from each water-bearing zone in the 29 reconnaissance borings were screened for volatile organic compounds using EPA Method 601 and were also analyzed for several inorganic parameters.

Task 6 - Aquifer Test Planning

Based on the results of the reconnaissance borings, a plan was developed for aquifer testing. This testing is necessary to provide data for extraction system design and ground-water modeling.

Task 7 - Selection of Well Construction Technology

Various drilling technologies were reviewed with respect to the application of the drilling methods to monitoring well installation. Methods for installation of monitoring wells were recommended based on anticipated total depth and lithologies likely to be encountered.

Task 8 - Sampling Material Study

Literature discussing the compatibility of sampling and well construction equipment with contaminant species in ground water was reviewed. Recommendations for preferred materials for monitor well screens casings were made. Other sampling equipment requirements were also defined.

Task 9 - Sample Equipment Design

Available well sampling equipment was reviewed with respect to

compatibility with contaminant species, ability to deliver an unaltered sample, ease of use, associated labor requirements, reliability, capital costs, and operation and maintenance costs. Both portable and dedicated pump systems were evaluated.

Task 10 - Sampling Protocol

It was assumed that monitoring wells both on base and off base would initially be sampled quarterly. (It is anticipated that the frequency of sampling will be reduced, with time, for some wells.) During the preliminary rounds of sampling identification of appropriate parameters for both organic contaminant screening and detailed contaminant characterization will be required. EPA Standard Methods to accomplish both of these objectives were identified in this task.

Task 11 - Hydrogeologic System Evaluation

Existing data regarding the hydrogeological system in the vicinity of McClellan AFB were reviewed with respect to future modeling efforts. It was determined that although the geology in the area is now more accurately understood, the aquifer parameters needed to input to a model are not adequately defined. Recommendations of means to acquire the needed information were made.

Task 12 - Model Selection/Acquisition

Based on available data, mass transport and advection models which simulate ground-water flow were reviewed for their applicability to the hydrogeologic setting in the vincinity of McClellan AFB.

For the first modeling task, two advection models were selected as the best alternatives for this hydrogeologic system. Possible contraints on mass transport modeling were also defined.

Task 13 - Monitoring Well Siting

A total of thirty locations were selected for future monitoring well installation, based upon the need to define contaminated areas, identify contaminant sources, and provide information on the horizontal and vertical dispersion of any contaminants. It is anticipated that twenty additional monitoring wells will be installed in a subsequent phase to further define the contaminated areas.

RESULTS OF ANALYSES

Water samples were collected from each saturated zone encountered during drilling of the reconnaissance borings. All samples were analyzed in the field for pH, conductivity, and temperature. Results of the field analyses are presented in Table 3.5-2. These data reveal no evidence to support the existence of distinct, hydraulically isolated aquifer zones. Eight inorganic species (Ca, CO_3, Cl, Fe, HCO_3, Mg, Na, and SO_4) were quantified in laboratory analyses as a further means of characterizing ground-water conditions. These data are presented in Table 3.5-4, and also suggest that the water-bearing zones sampled are not isolated, but rather are hydraulically interconnected.

Purgeable halocarbon compounds present in ground-water samples were determined using EPA Method 601. The compounds identified by this method, along with their respective detection limits, are listed in Table 3.5-6. The analytical results were compared to action levels or maximum contaminant levels (MCL's) established by the California Department of Health Services, 1983 (Table 3.5-8). Reconnaissance borings from which one or more ground-water samples was found to contain any of the EPA Method 601 compounds at concentrations exceeding these action levels are listed below:

Boring #	Compounds Exceeding Action Levels
RB-1	1,1 Dichloroethene, Methylene Chloride
RB-4	1,1 Dichloroethene
RB-5	1,1 Dichloroethene, 1,2 Dichloroethane, Vinyl Chloride
RB-6	1,1 Dichloroethene, 1,2 Dichloroethane, Trichloroethene
RB-12	1,1 Dichloroethene
RB-22	1,1 Dichloroethene

CONCLUSIONS

Detailed discussions of results for the 13 tasks completed during Phase II Stage 2-1 activities are provided within the corresponding Sections 3.1 through 3.13. Major conclusions drawn from those results, are provided in the following paragraphs.

Task 1 - Project Implementation

The principal result of Task 1 was the establishment of a computer database system to compile and manage the large volumes of data and information collected during Stage 2-1. The database and the associated Project File Sets will prove to be valuable for future environmental work on and around McClellan AFB.

Task 2 - Data Review

Radian collected and reviewed existing data regarding the environmental setting and previous environmental investigations in the vicinity of McClellan AFB from Air Force and agency personnel, from representatives of local water districts and from local drilling firms.

Applicable data were entered into the computer databases as either Site-Specific data (applying to a given point) or General Information (applying to all or part of the study area).

Most data reviewed were assigned confidence levels (confirmed, reliable, or questionnable) based upon the reliability of the information.

Task 3 - Well Inventory

The well inventory, which is discussed in Section 3.3, identified over 1,000 wells in the off-base area of interest. Approximately 62% of all residences in the area of interest responded in the well inventory. Data from the two rounds of community contacts were reduced to Site-Specific data and entered into the computer database. The well data can be recalled and listed by x-coordinate, y-coordinate, grid cells, well status, or other parameters.

Task 4 - Geologic Investigation Planning

The Geologic Investigation Planning task selected a drilling method to be used during exploratory drilling and the locations of the borings to be drilled. Dual-tube air-rotary drilling was selected because it is relatively fast, allows identification of saturated zones, provides good formation "cuttings" return to ensure accurate geological logging, and provides a means to obtain water samples representative of aquifer conditions.

Twenty reconnaissance boring locations were selected and were presented to Air Force and agency personnel. The agencies recommended nine additional borings be drilled and that all borings be extended to a depth of 200 feet. These recommendations were incorporated into the program.

Task 5 - Reconnaissance Borings

The reconnaissance boring program (Task 5) and associated activities developed a better understanding of near surface geology and hydrology in the vicinity of McClellan AFB. The following conclusions were developed as a result of these data:

- Geological units encountered within the first 200 feet below land surface (BLS) belong to the Victor Formation and probably the Laguna Formation. Characteristic white tuffaceous beds of the Fair Oaks Formation were not encountered or identified during drilling.

- All subsurface geologic units encountered are extremely heterogeneous. Sand, silt, and some gravel units are separated by lenses of clay. None of these deposits are correlatable over significant distances.

- Generally, clays decrease in abundance along north to south and east to west trends.

- Ground water occurs in an unconfined aquifer at depths from 90-120 ft BLS. In some areas, however, the first significant ground water was encountered below 120 ft BLS.

- Deeper ground-water zones occur in discontinuous sequences of sand and silt lenses, probably as semiconfined zones which are not laterally extensive.

- Ground-water flow appears to be generally southwest but significant deviation from this direction probably occurs in areas of extensive pumping. One such deviation is the apparent flow of ground water to the west and northwest in the vicinity of Area D.

- Ground-water quality is generally good, with low mineralization, except in areas of contamination. Organic compounds were detected west of Area D, in the area northeast of the base, and in lesser concentrations in areas west, southwest, and south of the base.

- Contaminants found near Area D have been transported by ground water, but contaminants found farther west of the base may have been transported initially within the surface waters of Magpie and Little Rio Linda Creek.

- The source of contaminants found south of the base are unknown. It is most probably that they are from base sources. However, other minor potential sources have been identified.

- Contaminants found northeast of the base are apparently upgradient of the base and a substantial distance from any McClellan waste area. The source of these contaminants is unknown. However, there is no apparent connection between these contaminants and any known waste disposal activities on base.

Task 6 - Aquifer Test Planning

As a result of Task 6, it was concluded that a comprehensive aquifer test, including the ability to induce a cone of depression, would be

necessary to detemine aquifer parameters and the interconnection of saturated zones. To accomplish this, a location west of the base was selected for testing, provided property access can be obtained. Area D is recommended for the large scale aquifer testing because it is near the area of greatest concern. The site has good accessability with adequate space to prevent interference from other wells during pumping. Since no significant contaminants were found the testing will be easier to conduct. Other off-base areas present difficulties in the form of access and a lack of sufficient distance from existing wells to ensure an unbiased test. The hydrogeology in Area D is representative of conditions throughout the McClellan area and so is a good place to best establish the aquifer parameters.

Task 7 - Selection of Well Construction Technology

Based on Task 7 activites, it was concluded that large diameter, hollow stem auger drilling would be the preferred drilling method of wells up to 120 feet deep. For deeper monitoring wells, air rotary drilling with casing drive is the preferred method. Both of these methods allow accurate identification of saturated zones.

Task 8 - Sampling Materials Study

The results of Task 8 indicate that monitoring wells should be constructed with stainless steel well screens and casing blanks through the wetted length of the well. Polyvinyl chloride (PVC) may be utilized as well casing above the static water level.

Sampling equipment should be limited to stainless steel and Teflon materials, including the pump and discharge lines.

Task 9 - Sample Equipment Design

A combination of dedicated and portable pumps will provide the most cost-effective means of sample acquisition. For all monitoring wells

completed in the uppermost aquifer, a portable system is most cost-effective. For deeper wells, where a large volume of water must be purged from the well before sampling, a dedicated pump with a packer above the screen is preferable.

Task 10 - Sampling Protocol

A sampling and analysis scenario was developed in Task 10. A detailed sampling protocol will be developed in future activities, once the sampling system has been chosen.

Assuming that the monitoring well network will be composed of 50 on base and 50 off base wells, this system should initially be sampled quarterly. With time it is anticipated that wells consistently not showing contaminants could be dropped from quarterly sampling to annual or semi-annual sampling.

Sample analysis should be conducted for volatile organic compounds by EPA Method 601. In addition, a second sample should be retained for analysis by gas chromatography - mass spectroscopy (EPA 624/625) if needed. Therefore, if the EPA 601 analysis requires species confirmation or if non-601 species are suspected, the GC/MS analysis may be conducted.

Task 11 - Hydrologic System Evaluation

Relatively little is known about aquifer parameters, flow, and quality in the off base area. In order to conduct flow modeling (advection modeling) it will be necessary to first determine aquifer parameters, especially leakage between zones, and to determine water levels in the off base area. Mass-transport (solute transport) modeling will require sampling and analysis of monitoring wells in the off base area and this sampling must encompass both horizontal and vertical controls in order to assess the potential for three-dimensional transport.

Task 12 - Model Selection/Acquisition

Flow modeling and mass transport modeling were evaluated in Task 12 for their applicability to the hydrogeologic environment surrounding McClellan AFB.

For the flow modeling effort, the models known as TRANS and USGS-MOC have been selected as being most suitable. Radian has acquired both of these modeling codes. No mass-transport model has been selected because it will be necesssary to evaluate the results and validity of the flow model first. Because only a few mass-transport models currently exist, the selection of a mass-transport model will be a minimal effort.

Task 13 - Monitor Well Siting

Monitoring wells to be installed off base in future activities will be installed in two phases. The first phase is estimated to include 30 wells and the second phase will include 20 wells. The locations of the first 30 wells were selected to emphasize areas of known contamination or where the contaminant source is in question. Thus, the first phase of monitoring wells are predominantly located near the base. It is anticipated that the second phase of monitoring well installations will be used to "fill-in" data gaps in areas of suspected contamination or extend the information beyond contamination identified in the first phase wells.

RECOMENDATIONS

Based on the findings of the Phase II Stage 2-1 study of McClellan AFB, a number of activities for Stage 2-2 are recommended. These recommendations are described in detail in Section 6.0 of this report, and are presented in summary fashion below:

- o Database Conversion - develop a means by which permanent and timely access to project data can be provided to Air Force personnel.

- o Aquifer Testing - conduct long and short term aquifer tests to acquire the raw data necessary to determine hydraulic characteristics of the aquifer.

- o Aquifer Test Evaluation - interpret the raw data from pump tests to determine aquifer characteristics including transmissivity, storativity, leakage coefficient, and anisotropy.

- o Acquisition of Monitor Well Access - obtain permanent access right-of-ways to any wells which must be placed on private property.

- o Monitoring Well Installation - First Phase - install, complete and develop the first 30 off-base monitoring wells at the locations previously identified by Radian.

- o On-base Monitoring Well Evaluation and Redevelopment - evaluate existing on-base monitoring wells for their ability to yield valid samples in their present condition and redevelop them, as necessary.

- o Sampling System Implementation - acquire and install ground-water sampling apparatus (well-dedicated and portable sample delivery systems).

- o Sampling Protocol Manual Development - provide guidance for training Air Force personnel or obtaining contractor services to accomplish monitoring well sampling.

- Monitor Well Sampling and Training - Radian will conduct two rounds of monitoring well sampling and provide instruction to Air Force personnel on proper sampling protocol.

- Sample Analysis - ground-water samples should be field tested for pH, conductivity and temperature and analyzed for EPA Method 601 and 602 compounds (purgeable organics) in the laboratory.

- Flow Model Implementation - implement the advection (flow) model to depict ground water movement based on the conceptual model currently being developed.

- Monitoring Well Siting - Second Phase - select locations for 20 additional monitoring wells based on results of the preceding ground-water analyses and subject to Air Force approval.

- Monitor Well Installation - Second Phase - install, develop, and complete 20 monitoring wells in selected key locations.

- Well Abandonment Study - review inactive wells in the off-base area to insure proper closure.

- Database Maintenance - maintain the existing project database with continuing updates.

- Base Environmental Activity Coordination - establish a committee or other mechanism (to include principal contractor's representative) to coordinate on- and off-base environmental activities.

1.0 INTRODUCTION

The United States Air Force (USAF) is currently engaged in a program to identify and mitigate impacts resulting from past solid waste handling and disposal procedures at their facilities. This program is known as the Installation Restoration Program (IRP) and is composed of four phases. Phase I consists of Installation Assessments (Records Searches); Phase II is a confirmation of the existence or absence of contamination which is divided into Stage 1 (qualitative) and Stage 2 (quantitative) investigations; and Phase III is a Technology Base Development in which research and development of remedial action techniques will be conducted. In Phase IV, Operations, remedial action plans are designed and implemented.

In January 1984, Radian Corporation was directed to prepare a Presurvey Report to accomplish certain Phase II activities at McClellan Air Force Base (AFB) near Sacramento, California. These activities focused primarily on areas surrounding the base and were designated "Stage 2" activities. The Presurvey Report "Phase II Follow-On Monitoring Presurvey, Installation Restoration Program, McClellan AFB, California" was delivered to the United States Air Force Occupational and Environmental Health Laboratory (USAF/OEHL) on 10 February 1984. That report identified 10 tasks, divided into 30 subtasks, for the entire Phase II-Stage 2 program. The original tasks and subtasks are listed in Table 1.0-1.

After submission of the original Presurvey Report, USAF/OEHL determined that the project should be accomplished in a phased approach. The first series of tasks were termed Phase II, Stage 2-1 and began 15 May 1984 under Delivery Order 16, contract F33615-83-D-4001. Table 1.0-2 lists the 13 tasks accomplished in Stage 2-1 and the corresponding "Actions" listed in the Delivery Order.

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TABLE 1.0-1. LISTING OF TASKS AND SUBTASKS PROPOSED IN ORIGINAL PRESURVEY REPORT FOR PHASE II--STAGE 2

Task 1	DATA REVIEW
1A	Program Implementation
1B	Historical Data Review
Task 2	WELL SURVEY
2A	Well Inventory
Task 3	GEOLOGIC CONDITIONS
3A	Geologic Evaluation Planning
3B	Reconnaissance Borings
3C	Aquifer Test Planning
3D	Aquifer Testing
3E	Data Evaluation
Task 4	MONITORING WELL SITING
4A	Monitor Well Planning
Task 5	WELL CONSTRUCTION
5A	Drilling Assessment
5B	Monitoring Well Installation
Task 6	SAMPLING EQUIPMENT
6A	Materials Assessment
6B	Sampling Design
Task 7	SAMPLING PROTOCOL
7A	Sampling Protocol
Task 8	SAMPLING/ANALYSIS
8A	Well Sampling
8B	Sample Analysis
8C	Training
Task 9	MODELING
9A	Data Evaluation
9B	Model Selection
9C	Model Implementation
9D	Data Reduction
9E	Transport Modeling
Task 10	REMEDIAL ACTIONS
10A	Criteria Development
10B	Identification & Screening
10C	Alternatives Development
10D	Alternatives Costing
10E	Environmental Assessment
10F	Cost Effectiveness Evaluation
10G	Recommendations

TABLE 1.0-2. LISTING OF DELIVERY ORDER 16 ACTIONS AND CORRESPONDING TASKS FROM ORIGINAL PRESURVEY

Delivery Order 16 Actions	Original Presurvey Tasks	Task Numbers for This Report
Action 1 - Development of Data Base Management System	1A - Project Implementation	1
	1B - Historical Data Review	2
Action 2 - Comprehensive Well Survey	2A - Comprehensive Well Survey	3
Action 3 - Geologic Evaluation	3A - Geologic Evaluation Planning	4
	3B - Reconnaissance Borings	5
	3C - Aquifer Test Planning	6
Action 4 - Selection of Well Construction Technology	5A - Selection of Construction Technology	7
Action 5 - Well Sampling Equipment and Strategy	6A - Materials Investigation	8
	6B - System Design	9
	6C - Sampling Strategy	10
Action 6 - Contaminant Transport Modeling	9A - Hydrogeologic System Evaluation	11
	9B - Model Selection and Requisition	12
Action 7 - Off-Base Monitoring Well Selection	7A - Off-Base Monitoring Well Site Selection	13

This report defines the activities completed in Phase II, Stage 2-1. It is divided into two volumes: Volume 1: Report Text and Plates, and Volume 2: Appendices. The 13 Appendices in Volume 2 are numbered to correspond to the 13 tasks accomplished which are detailed in Volume 1, Sections 3.1 through 3.13.

Sections included in Volume 1: Report Text and Plates, are the Environmental Setting (2.0), Field Program (3.0), Discussion of Results and Significance of Findings (4.0), and Recommendations (5.0).

2.0 ENVIRONMENTAL SETTING

The following discussion of the McClellan AFB Environmental Setting is principally derived from the Installation Restoration Program Phase I Records Search Report (CH2M-Hill, 1981), and from the IRP Phase II Stage I Report (Engineering-Science, 1983). This section is incorporated into this report for the purpose of achieving completeness in a single document and adhering to standard OEHL Phase II report format.

2.1 Geographic Setting and Land Use

McClellan AFB is located northeast of Sacramento, California as shown in Figure 2.1-1. The base includes 2,598 acres within the main installation boundaries. In addition to the 2,598 acre installation, McClellan AFB supports 978 acres of remote facilities as follows:

Davis Communications Annex	316 acres
Lincoln Communications Annex	356 acres
Capehart Family Housing Annex	217 acres
Camp Kohler Annex	35 acres
McClellan Storage Annex	52 acres
Sacramento River Dock Annex	1.7 acres
Middle Marker Annex	0.3 acres

2.2 Physiographic Features

McClellan AFB and off-site facilities are all located in the Great Valley Physiographic Province. This province extends from Red Bluff to the north to Bakersfield, approximately 400 miles to the south (California Department of Water Resources, 1974). The valley averages 40 miles in width. The Sacramento and the San Joaquin River Valleys together form the Great Valley Physiographic Province (California Department of Water Resources, 1974, 1978). In the McClellan area, the Sacramento Valley is

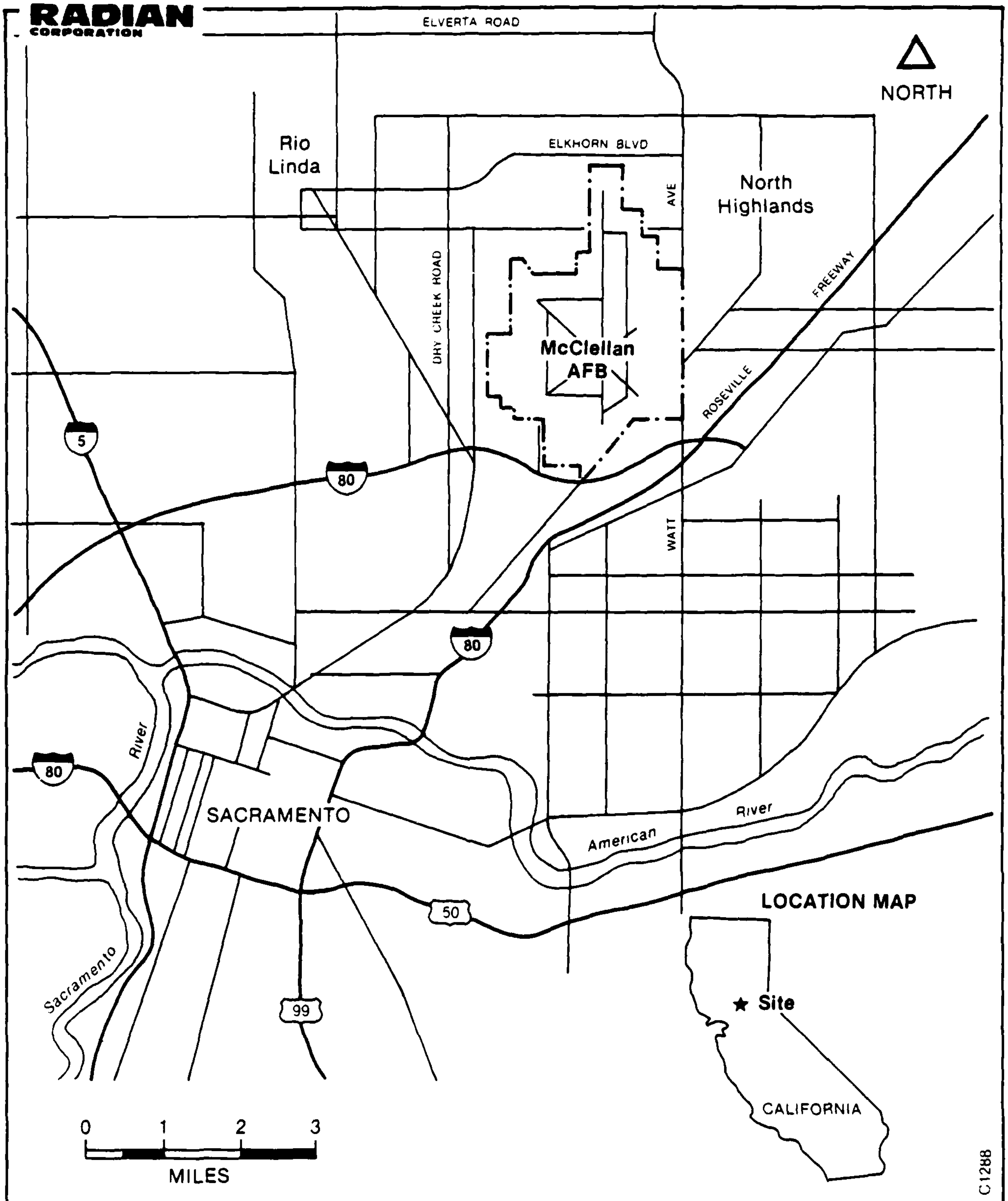

Figure 2.1-1. Location of McClellan Air Force Base

further subdivided into the American Basin, the Yolo Basin, and alluvial plains of the Sacramento River. McClellan AFB is located within the alluvial plain.

The relatively flat topography at McClellan is typical of an alluvial plain. Elevations range from 75 feet above mean sea level (msl) on the east side of the base to approximately 50 feet above msl on the west side. The flat plain is dissected slightly by tributaries of the Sacramento and American Rivers.

Magpie Creek is the most prominent natural drainage feature at McClellan AFB. This creek, modified somewhat by channelization, traverses the base from east to west discharging to the Natomas East Main Drainage Canal and ultimately to the Sacramento River.

The natural drainage patterns at McClellan AFB have been modified by construction of a series of storm drains. Runoff from streets and runways is directed into this system and conveyed westward leaving the base through Magpie or Arcade Creeks.

2.3 Climate

Previous reports for Phase I and II of the Base IRP (CH2M-Hill, 1981; Engineering-Science, 1983) characterized the climate of the Sacramento Valley as Mediterranean to subtropical. Hot, dry summers and cool, moist winters are common to this type of climate.

Average temperatures in the Sacramento Valley range from the mid-40's (Fahrenheit) during the winter months, to the mid-70's during the summer. The average annual temperature is about 60°F.

During the summer, maximum temperatures frequently reach 90°F and often exceed 100°F. Minimum winter temperatures seldom drop below 20°F. Temperatures may vary from 25° to 40° per day during the summer months with less variation occurring during the winter.

The bulk of precipitation in the area falls during the spring and winter. About 17 inches of the 19.8 inch average annual precipitation occurs from November to April. Over one-half of the total average rainfall occurs during the months of December, January, and February. The Sacramento Valley seldom receives snowfall.

The mean annual evapotranspiration rate for the Sacramento area is about 45 inches per year. The net precipitation for the area (mean annual precipitation minus the mean annual evapotranspiration) is about -26 inches per year.

2.4 Biota

McClellan AFB contains about 416 acres of unimproved lands. The predominant plant community at McClellan AFB, and in most of the surrounding region, is the valley grassland. Riparian forests and vernal pools also occur within or in close proximity to McClellan, though their acreage is very small (CH2M-Hill, 1981).

A brief field survey of fauna present on McClellan AFB was conducted by CH2M-Hill on 30 April 1981. During that time, one fish, one amphibian, one reptile, two mammal, and 24 bird species were sighted. The blacktail hare is probably the largest mammal permanently residing on-base. Muskrats were also observed at a number of locations on Magpie Creek. In regard to birds, game species such as pheasant, mourning dove, and California quail are common on the site, though they are not hunted. Mallards were observed in Magpie Creek and (together with pintails) in the flooded grasslands at the Davis site.

The vertebrate fauna of Magpie Creek are limited primarily to mosquitofish, waterfowl, muskrats, and amphibians. A study in 1973 (Pauls, C. F. and Doane, J. R., 1973, "Comprehensive Survey of Magpie Creek," McClellan Air Force Base, California, USAF Env. Health Laboratory) documented the macroinvertebrate fauna of the creek. Both densities and diversity were limited in the concrete-channelized portions of the creek where little natural substrate was available. Sludge worms (Tubifex) were the only species found upstream of McClellan AFB, where the San Six Wastewater Treatment Plant provides most of the flow. Proceeding downstream, damselfly (Ischnura), Psychoda fly, and mosquito larvae become more prevalent.

Only two endangered plant species are known to occur within Sacramento County. These are Sacramento orcutt grass (Orcuttia viscida), which occurs in the vicinity of Phoenix Field, and Boggs Lake hedge hyssop (Gratiola heterosepala), which is found in the vicinity of Rio Linda (CH2M-Hill, 1981).

Only three endangered wildlife species are expected to occur within 25 miles of McClellan AFB: the bald eagle, peregrine falcon, and giant garter snake. According to Craig and Gustafson, as quoted by CH2M-Hill, the nearest eagle nest sites are near Lake Pillsbury (Mendocino County) and in the vicinity of Chico (Butte County). However, juveniles or non-breeding eagles occasionally pass through the Sacramento area. Peregrine falcons regularly migrate through Sacramento County, and it is possible some may reside there. The giant garter snake is confined to sloughs, marshes, and other permanent freshwater areas, and its nearest known location is in the major riverine systems and associated wetlands south of Sacramento.

Most of the unimproved grassland areas on McClellan AFB have been disturbed at one time or another. Much of Magpie Creek has been cleared of former riparian vegetation and channelized. Some of the vernal pool areas of the creek have been ditched or filled in. However, many of these actions

took place in the past, and the existing vegetation growing on the unimproved areas of McClellan is generally healthy, vigorous, and supporting the appropriate fauna.

Magpie Creek has been affected due both to its physical modification and the effluent from the San Six County Wastewater Treatment Plant located above McClellan. In 1977, a fish kill of 100 to 150 minnows took place in Magpie Creek and was ultimately traced to high chlorine residuals originating from the county treatment plant. This problem has since been corrected.

In regard to hazardous wastes, the use of persistent and later non-persistent pesticides for mosquito control on base has undoubtedly affected the natural invertebrate fauna of Magpie Creek and the vernal pools. This impact is considered to be minor. There is not evident stress on biota due to the use and disposal of hazardous wastes at McClellan AFB. Further details on the biota of McClellan AFB are included in Appendix E of the Phase I Report prepared by CH2M-Hill, 1981.

2.5 General Hydrogeology of McClellan AFB

The general description of the hydrogeological environment of McClellan AFB provided in this section is based on published literature and information obtained from Base production wells and Base monitoring wells. A more detailed description of the hydrogeology is presented in Section 3.5, which discusses the results of the Phase II, Stage 2-1 field program.

McClellan AFB is underlain by sediments from the Victor Formation (California Department of Water Resources, 1974, 1978). The thickness of these sediments varies, but they could be up to 50 feet thick beneath the base. Underlying the Victor Formation are the Fair Oaks and Laguna Formations. The Fair Oaks Formation ranges in thickness from 0 to 225 feet and the Laguna ranges from 0 to 200 feet in thickness (CDWR, 1974). The diag-

nostic white clays that characterize the Fair Oaks Formation were noticed during monitoring well installation on the western side of the base at depths ranging from 70 to 75 feet. Sediments from the Mehrten Formation underlie the Fair Oaks and Laguna Formations, ranging in thickness from 40 feet to as much as 500 feet along the axis of the Great Valley (California Department of Water Resources, 1974).

Downgradient of the base to the south, the top of the Victor Formation surfaces near the Sacramento River. The base of the formation dips beneath the river where it is eventually overlain by alluvial deposits. The Victor Formation is a wedge-shaped plain thickening from east to west, with an increase in fine-grained material in that direction (California Department of Water Resources, 1978).

Base water supply wells are completed within the Fair Oaks, Laguna, and Mehrten Formations from about 150 to 400 feet below the ground surface. Well logs from the installation of Base production wells indicate great variety in subsurface conditions at each well location. Layers of sand, silt, and clay appear to be alternating in no specific sequences or consistent thicknesses, indicating the possible discontinuous and lenticular nature of the sediments.

Geologic logs from monitoring wells installed by the Base in 1980 and subsequent water level readings in those wells have indicated water-bearing sands at a depth of approximately 100 feet (about 20 feet below mean sea level). During Phase II monitoring well installations, water was also generally encountered in that depth range.

The regional ground-water flow direction is to the south-southwest toward a pumping trough south of Sacramento. South and west of McClellan AFB are numerous active private and public water supply wells that influence the immediate local ground-water flow.

Principal recharge areas for the water-bearing sands underlying McClellan AFB are east of the Base in the Sierra Foothills. Recharge areas for the shallow sands are located closer to the Base than the recharge areas for the deeper water-bearing sands. Discharge from the ground-water basin occurs mainly as pumpage.

2.6 Surficial Soil

Most of the soil cover at McClellan AFB consists of a sandy loam, referred to as San Joaquin sandy loam, to a depth of approximately 4 feet (SCS, 1954). The surface soil is moderately permeable, but the subsoil has a very low permeability. Surface runoff from this soil is slow to medium. The soil has a low available water holding capacity and a slight erosion potential.

2.7 Lithology

McClellan AFB is located in a deep sedimentary trough that received sediments from the Sierra Nevada Mountain Range. Most of these sediments were transported to the valley by numerous tributaries to the meandering Sacramento River. Since post-Eocene time (about the last 60 [sic] million years), up to 4,000 feet of nonmarine sediments and volcanic detritus have been deposited in the valley. The deposited sediments resemble a wedge, relatively thin by the Sierras in the east and with maximum thickness near the Coast Ranges to the west. The sedimentary wedge slopes gently to the west, ranging from 300 feet per mile to as little as 5 feet per mile in the Sacramento County area (California Department of Water Resources, 1974).

In northern Sacramento County, surface sediments are part of the Victor Formation, underlain by the Fair Oaks, Laguna and the Mehrten Formations. The Victor Formation underlies the Victor Plain, a broad alluvial plain extending from south of Sacramento to the northern county boundary.

From the east, this formation dips below the American River and surfaces near the Sacramento River as a low ridge with a maximum elevation of 26 feet. The upper surface of the formation slopes about 5 feet per mile and the base slopes at about 11 feet per mile in an east-west direction, indicating a gradual thickening to the west. Sediments within the Victor Formation consist of interbedded granitic sand, silt, and clay with occasional lenses of metamorphic channel gravels. The sediments are heterogeneous and laterally and vertically discontinuous, typical of a fluvial depositional environment. A great variability in grain size within this unit is the result of deposition in intricately braided channels. Hardpan is typically encountered in the upper portion of the stratigraphic column. The formation has an overall moderate permeability, generally yielding little water unless old stream channels are penetrated (California Department of Water Resources, 1974).

The Fair Oaks Formation underlies the Victor Formation near McClellan AFB. This formation slopes westward at about 15 feet per mile, and may reach thicknesses of over 100 feet. These sediments also consist of poorly bedded sands, silts, and clays, with occasional lenses of gravel. The formation is characterized by the presence of white clay beds (white volcanic tuff) up to one foot thick. The Fair Oaks Formation, like the Victor Formation, yields little water to wells except where wells penetrate channel deposits. In those instances, well yields may be up to 3,500 gallons per minute (gpm) with drawdowns in the order of 30 feet (i.e., specific capacities of about 120 gpm per foot of drawdown) (California Department of Water Resources, 1974).

The Fair Oaks Formation laterally interfingers with the Laguna Formation in and around McClellan AFB. The Laguna Formation is a predominantly fine grained, poorly bedded, somewhat compacted continental deposit. The thickness of the formation ranges between 125 to 200 feet. This formation is an extremely heterogeneous assemblage of silt, sand, clay, and lenticular gravel beds. The most common deposits are light gray to yellow

brown clayey silt to silty fine-grained sand. Clean, well-sorted sand occurs chiefly in relatively thin, laterally extensive zones. Gravel beds are scarce, poorly sorted and of low permeability. The sands are of granitic origin, with abundant weathered feldspars, biotite, and quartz grains. The sediments of the Laguna Formation are locally variable. Mica flakes are locally abundant and serve as a distinguishing character for the bulk of the formation. The Laguna and Fair Oaks Formations apparently are correlative in the upper sections beneath the Victor Formation in the McClellan area. The major difference between the Fair Oaks and the Laguna Formations is the presence of the white tuffaceous clay layers in the Fair Oaks Formation.

The Mehrten Formation consists of two distinct units. The first unit is a sedimentary deposit which consists of gray to black sands interbedded with blue to brown clay. The other unit is a hard, gray volcanic tuff-breccia (California Department of Water Resources, 1974). No sediments recognized as Mehrten were detected during the drilling program.

2.8 Ground Water

Ground water within the Sacramento Valley basin occurs as a result of in-stream percolation into underlying permeable materials, direct infiltration of precipitation, or irrigation return. Recharge areas for that part of the basin underlain by hardpan (e.g., McClellan AFB) are along the eastern basin margins. Hardpan severely restricts downward movement of water, except where fractured.

Ground-water discharge occurs almost exclusively by pumping. Since the turn of the century, extensive ground-water pumping for irrigation, industrial, domestic, and municipal usage has dramatically altered the ground-water flow directions and gradients in the basin. Water is pumped primarily from the Fair Oaks, Laguna, and Mehrten Formations in the Sacramento areas. Shallow ground-water flow in the area of the base is mainly to the southwest, under the influence of regional pumping.

Ground-water quality in the McClellan AFB area is naturally excellent for irrigation and domestic use. The chemical characteristics of this ground water are reflective of its origin, containing calcium, magnesium, and calcium-sodium bicarbonate. In Sacramento County, the fresh ground-water zone ranges in thickness from several hundred feet, near the eastern portion of the county, to an estimated 2,000 feet near the Sacramento River. The thickness of the fresh water zone at McClellan AFB is approximately 1,385 feet (CH2M-Hill, 1981).

2.9 Past Waste Disposal Practices and Ground-Water Quality Problems

Past waste disposal operations at McClellan AFB include the use of landfills, burial pits, open burning, incineration, sludge drying beds or landfarms.

The Phase I Report identified 46 waste disposal and storage sites at McClellan AFB (CH2M-Hill, 1981). Figure 2.9-1 shows the general locations of these sites. Table 2.9-1 lists each disposal site along with information obtained from historical records and personnel interviews regarding site usage, period of use, materials handled, and the estimated size. Not all of the sites listed contained hazardous materials.

As a result of some of the waste disposal practices on base, waste materials and leachates have entered the local ground-water system. Several on-base production wells and off-base municipal supply and private wells have been been shut down due to the presence of industrial organic compounds in the ground water. The highest concentration of organic contaminants were noted by previous investigators to exist along the western boundary of the base, within shallow water-bearing units.

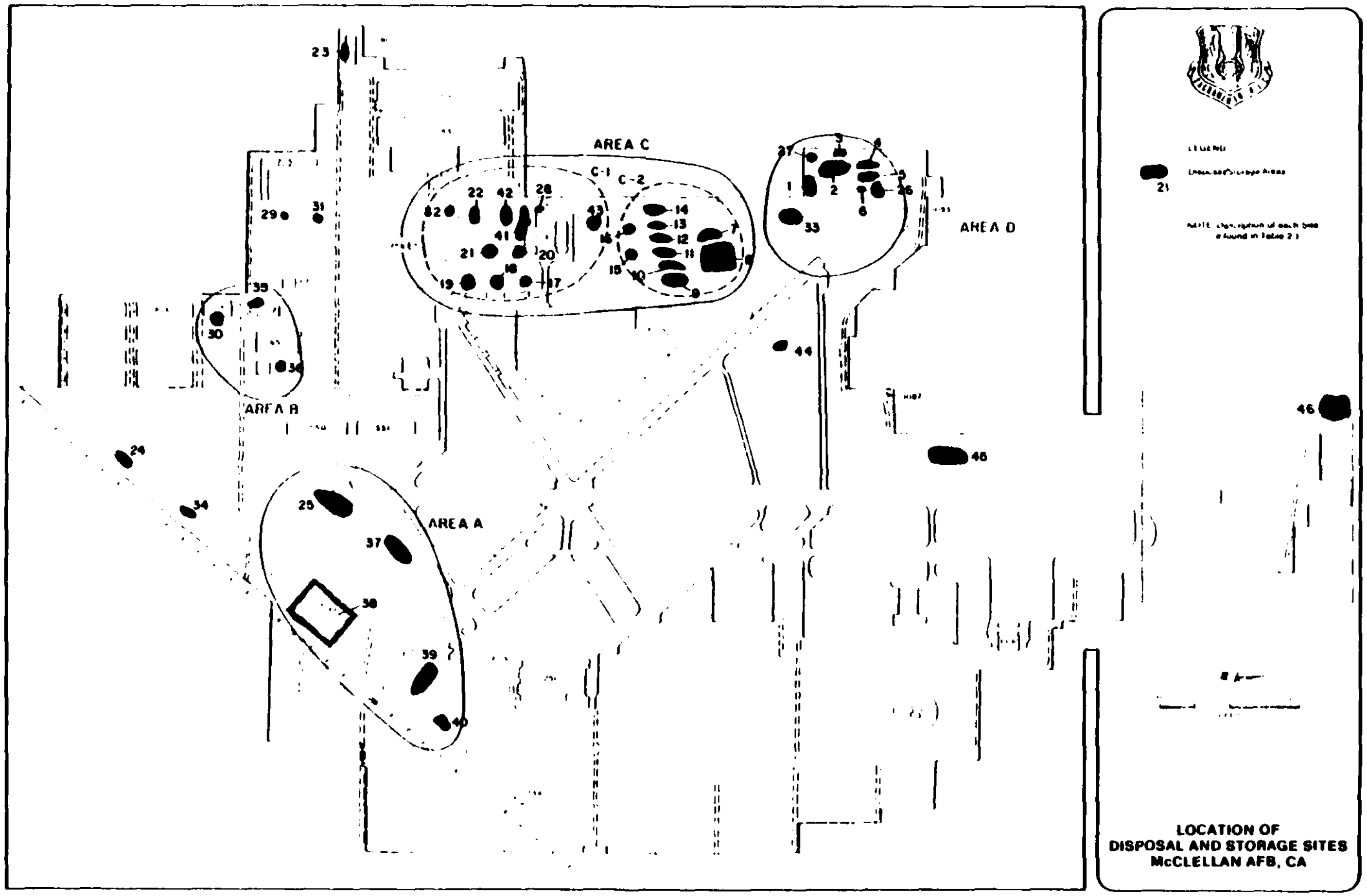

Figure 2.9-1. Location of Disposal Areas

(From Engineering-Science, 1983)

TABLE 2.9-1. DISPOSAL AND STORAGE SITES IDENTIFIED IN PHASE I, McCLELLAN AFB, CALIFORNIA

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
1	Buring/burial pit	1959-1962	Refuse/solid waste	310 ft x 190 ft
2	Sludge/oil pit Refuse burning/burial pit	1962-1979	Refuse/solid waste; undewatered industrial sludge; oil; waste solvents; TCE-contaminated wastes	300-400 ft x 50 ft x 30 ft deep
3	Sludge/burning/burial pit	1962-1965	Undewatered industrial sludge; oil	300-400 ft x 50 ft x 30 ft deep
4	Sludge/oil pit	1967-1981	Undewatered industrial sludge; oil; TCE-contaminated wastes	300-400 ft x 50 ft x 30 ft deep
5	Sludge/oil pit	1972-1978	Undewatered industrial sludge; oil; waste solvents; TCE-contaminated wastes	300-400 ft x 50 ft x 30 ft deep
6	Oil burn pit	1972-1978	Oil; fuel; solvents	125 ft x 125 ft
7	Sludge/oil pit	1966-1977	Undewatered industrial sludge; oil; TCE-contaminated wastes	300-400 ft x 50 ft x 30 ft deep
8	Sludge/burial pit	1974-1981	Dewatered industrial sludge; demolition debris; creek debris; paint chips and residues; sanitary sewage sludge (grit); TCE-contaminated wastes	400 ft x 40 ft x 30 ft deep
9	Burial pit	Pre-1949-1953	Ash and partially burned residue from Sites 22 and 31; dewatered industrial wastewater treatment plant sludge; Plating bath solutions and sludges (including lead, tin, antimony, and possibly	100-400 ft x 50 ft x 30 ft deep

(Continued)

TABLE 2.9-1. (Continued)

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
9 (Continued)			cadmium plating wastes; degreasing solvents and sludges; paint residues; fuels (probably including leaded) and oils; PCB liquids, solids, transformers, and electrical components; miscellaneous laboratory chemicals; cyanide wastes (drummed); low-level radioactive wastes (possibly); herbicide/pesticide containers	
10	Burial pit	1953–1955	Same as Site 9	Same as Site 9
11	Burial pit[2]	1955–1957	Same as Site 9	Same as Site 9
12	Burial pit[2]	1967–1969	Same as Site 9[3]	Same as Site 9
13	Burial pit[2]	1969–1971	Same as Site 9[3]	Same as Site 9
14	Burial pit	1971–1974	Same as Site 9	Same as Site 9
15	Sodium valve trench	1940–1950	Sodium valves from aircraft engines	15–20 ft x 2 ft x 6–9 ft deep
16	Sodium valve trench	1940–1950	Sodium valves from aircraft engines	15–20 ft x 2 ft x 6–9 ft deep
17	Burial pit	1957–1959	Same as Site 9	Same as Site 9
18	Burial pit	1957–1959	Same as Site 9	Same as Site 9
19	Burial pit	1957–1959	Same as Site 9	Same as Site 9

(Continued)

TABLE 2.9-1. (Continued)

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
20	Sludge/oil pit	1956-1957	Industrial wastewater treatment plant sludge; oil	250 ft x 190 ft
21	Sludge/oil pit	1956-1957	Industrial wastewater treatment plant sludge; oil	250 ft x 220 ft
22	Burning pit/teepee burner/burial pit	1946-1968	Refuse, ash and residue; oily wastes; waste solvents (including TCE in significant amounts; waste chemicals	100 ft x 400 ft x 50 ft
23	Burial pit	1966-1969[4]	No information available	125 ft x 280 ft
24	Burning/burial pit	1964-1969	Demolition debris; scrap material (lumber and paper)	310 ft x 160 ft
25	Burial pit	1940s & early 1950s	No information available	625 ft x 250 ft
26	Sludge pit	Early 1960s	Undewatered industrial sludge	300-400 ft x 50 ft x 30 ft deep
27	Sodium valve trench	Late 1940s & early 1950s	Sodium valves from aircraft engines	15-20 ft x 2 ft x 6-9 ft deep
28	Creek debris sludge pit	Pre-1972	Creek debris/sediments; industrial waste spills and discharges (probably)	160 ft x 250 ft
29	Civil Engineering reclamation yard, transformer storage area, and scrap material burner	1950s & 1960s	Drums; transformers (some with PCBs)	160 ft x 250 ft
	Generator burial pit	1974	Aircraft generators (approximately 50-60)	

(Continued)

TABLE 2.9-1. (Continued)

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
30	Surface disposal site	Late 1950s - present	TCE; freon; diethyl ether; low-level radioactive wash water	220 ft x 220 ft
31	Refuse incinerator/ ash burial	1963-1968	Refuse/solid waste; ash	160 ft x 250 ft
32	Radioactive/hazardous waste storage	Pre-1963-1975	Low-level radioactive waste containers	160 ft x 160 ft
33	Industrial sludge land-farm	1972[5]	Industrial waste treatment sludge	350 ft x 250 ft
34	Waste solvent storage tanks	1950-1953	Waste solvents (2 underground tanks)	310 ft x 125 ft
35	Scrap metal burial pit	World War II[6]	Scrap strapping steel	220 ft x 160 ft
36	Open storage area	1958-1980	Plating shop chemicals	125 ft x 190 ft
37	Burial pit	Early 1950s[7]	Refuse	500 ft x 250 ft
38	Engine repair shop; carbon remover, storage/ burial/sludge pits	1940s-mid 1960s	Carbon remover, including ethylene, dichloride/cresylic acid/soap emulsion mixture and 50-50 mixture of cresylic acid/orthodichlorobenzene (large quantities in above and below-ground tanks); contaminated carbon removal sludges from skimming ponds	875 ft x 595 ft
39	Burning/burial pit	Pre-1941-1946	Refuse/ash; all base wastes	625 ft x 160 ft

(Continued)

TABLE 2.9-1. (Continued)

Site[1]	Prior Use	Dates in Use	Probable Materials Handled	Estimated Site Site
40	Industrial sludge drying beds (8, unlined)	1955-1972; 1980	Industrial wastewater treatment plant sludges in 4 beds (probably with significant concentrations of VOCs)	250 ft x 190 ft
41	Burial pit	Mid-1940s	Demolition debris (probably)	560 ft x 190 ft
42	Oil storage/burning/ burial pits (3 parallel burial pits and 2 burning pits)	Mid-1940s-1960s	Oil; waste fuel; waste solvents; refuse	190 ft x 310 ft
43	Burial pit	Mid-1940s	Demolition debris (probably)	220 ft x 250 ft
44	Hazardous waste storage area	1975-Present	No information available	500 ft x 150 ft
45	Paint burial pit	1950s	Latex-based(?)paint (approximately 200-300 55-gallon drums)	560 ft x 160 ft
46	Salvage yard operation (under previous owner)	Mid-1960s-1978[8]	No information available (identified PCB surface contamination; possible burial pit)	500 ft x 375 ft

Source: Engineering-Science, 1983

[1]Site locations are shown on Figure 2.9-1.
[2]Fire training is currently conducted in the vicinity of the site.
[3]Cyanide wastes were possibly removed from Site 12 or 13 during 1967-1971.
[4]Material was removed in 1970.
[5]Temporary (2-to-4 months).
[6]Material was removed in 1950.
[7]Material was removed in 1956.
[8]Material was removed in 1981.

3.0 FIELD PROGRAM

The field program discussed in this section is composed of 13 tasks which are the work elements of the IRP Phase II, Stage 2-1 at McClellan AFB. These tasks are discussed in corresponding subsections 3.1 through 3.13 and represent both field activities, such as drilling, and non-field tasks completed in Radian offices.

3.1 Task 1 - Data Management

3.1.1 Objective

Phase II, Stage 2-1 of the IRP for McClellan was essentially an information collection project. The Data Review and Well Inventory tasks alone required the collection, reduction, and evaluation of large quantities of information. In order to properly manage these data, a computer data management system was developed.

3.1.2 Approach

The approach used to develop the database management system involved the selection and assembly of system hardware and software, and the development of the database configurations. These are discussed in the following paragraphs.

System Hardware

The hardware components selected for the data management system are described below.

- IBM Personal Computer-XT: This unit was the principal component in the day-to-day data management. The unit contains 512K bytes of Random Access Memory (RAM) and a hard disk which

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allows 10 megabytes of data storage (10 million bytes) as well as a 5 1/4" floppy disk unit.

- IBM Personal Computer: Similar to the IBM-PC/XT but contained 256K bytes of RAM and two floppy disk drives. This unit served as a back-up to the 'XT' unit and handled certain data matrices as they were being compiled.

- Hayes Smart-Modem: A communications modem which allowed communications between the IBM-PC/XT, other IBM units, and the mainframe computer.

- Univac 1100 Mainframe: This unit was utilized primarily to develop project maps. Files of data and program instructions were sent to the Univac from the IBM-PC/XT, via modem.

- (4800 BAUD) Modem: This high-speed communications modem allowed transmittal of completed maps from the Univac to the study team.

- Remote Job Entry Terminal (RJE): The RJE unit received data from the Univac, via modem, and served as the control unit for the data, routing it to output or storage units.

- RJE Peripherals: These units included a 300 line per minute 'chain' printer, a magnetic tape drive (both Unitec products), and a 36 inch Calcomp plotter. Incoming Univac output was printed, stored on tape, and later plotted.

System Software

The primary software programs selected for the data management system (not including standard operating system software) included:

- Knowledge Manager: a data management package for personal computers,
- Lotus 1-2-3: a spread-sheet program allowing data handling in flexible matrices,
- PC Talk: a program which allows communications between computers, and
- CPS-1: a mainframe software package for contour plotting developed by Radian.

Database Configurations

Several computer databases were established to handle various types of data or to handle data in different formats. The primary databases are discussed below:

- Site Specific Database: This numeric database was established to handle information at individual points within the study area. To accomplish this, the area of interest was first established which encompassed the base itself and areas surrounding the base, primarily in the assumed direction of contaminant movement. The area of interest was then divided into grid-cells, each cell 1000 ft. square. The grid-cells and

actual footage coordinates originate in the southwest corner of the grid, listing the X-value (west to east) before the Y-value (south to north) as a standard Cartesian system. Figure 3.1-1 shows the area of interest and the grid-cell overlay.

When information was collected for a specific point in the study area (such as a well), the information was placed on a Site Specific form and entered into the computer database. An example of the Site Specific data form is given in Appendix 1. The Site Specific data could then be recalled by x,y coordinates, x,y grid cell, data entry number, or by individual parameters.

- General Information Database: The general information database was designed to accommodate information not specific to a given coordinate (e.g., regional geology) or to make text comments regarding a coordinate point. The input data were compiled on general information forms or at the bottom of site specific data forms. From these hard copies, information was entered in text form using a word processing package. An example of the General Information form is given in Appendix 1.

- Bibliographic Database: A bibliographic database was established to list and annotate those books, reports, and articles reviewed as part of the project and to list personal contacts which provided information. An example of the Bibliographic form is given in Appendix 1.

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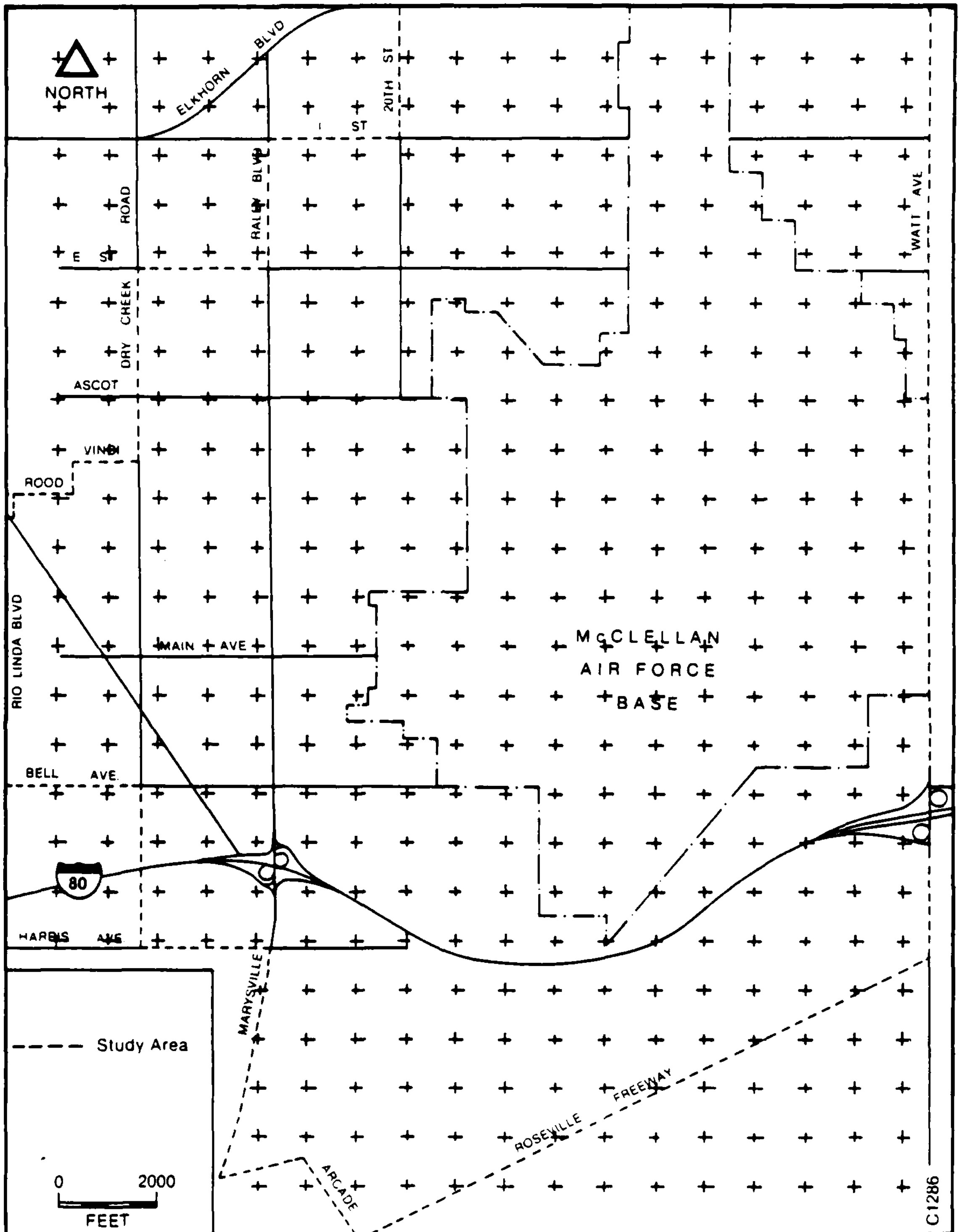

Figure 3.1-1. Study Area with Grid Cell Markings

3.1.3 Results

The result of the data management task is that an organized system was implemented to store, maintain and access large volumes of varied information. The system included the means to interface with Radian's mainframe computer for plotting and contouring routines.

3.1.4 Conclusions

The computer database system developed to accommodate large data volumes created during Stage 2-1 activities, is a powerful, expandable system. It is recommended that the database management system, including the data content, be converted to a base-usable system. This will allow base personnel to access the data and to expand the database as additional information becomes available.

3.2 Task 2 - Data Review

For the data review task, Radian acquired and reviewed available information pertaining to environmental conditions in the area of McClellan AFB. Data review efforts were initiated immediately following the issuance of the Phase II, Stage 2-1 Delivery Order. The majority of this task was accomplished during the first few weeks of the investigation. However, task efforts continued throughout the period of the investigation as new/additional information sources and/or requirements were identified.

3.2.1 Objectives

The objective of the data review task was to collect and review available environmental information for Phase II, Stage 2-1 of the McClellan AFB Installation Restoration Program (IRP). Data collected and reviewed were to be incorporated into computer databases along with data developed during the Stage 2-1 field investigation.

3.2.2 Approach

Existing information on environmental conditions in the study area was obtained from numerous sources. Following the completion of the acquisition activities, the information was reviewed and selected data were assimilated into the site-specific and general information file sets and computer databases. Data acquisition, review and assimilation efforts are discussed below.

3.2.3 Results

3.2.3.1 Data Acquisition

At the beginning of the data acquisition effort, Radian attended a meeting at the California Regional Water Quality Control Board, Central Valley Region (CRWQB, CVR) offices in Sacramento, California. The purpose of

the meeting was to discuss the general objectives of the data acquisition efforts. The meeting was attended by representatives of the following organizations:

- California Department of Health Services;
- California Regional Water Quality Control Board, Central Valley Region (CRWQCB, CVR);
- Sacramento County Health Department; and
- United States Air Force, McClellan AFB, Bioenvironmental Engineering.

During this meeting, Radian requested all relevant information for review. Materials received included data from the off-base sampling and analysis effort, drillers' logs for on- and off-base wells, results of the CRWQCB off-base well survey (conducted for the southwest portion of the study area), assessor's maps and rolls for parts of the study area and a summary of off-base chemical analysis for wells near the base. Agency/government and commercial contacts were identified by attendees as sources for possible future information needs. Data and information received at this meeting were catalogued and posted on the Bibliographic Database. The Bibliographic Database has been included in Appendix 2-A.

Radian also met with personnel from McClellan AFB Bioenvironmental Engineering to discuss the study and acquire necessary information. Materials received at this meeting included the following reports:

- Final Report for Investigating Ground-Water Contamination as of 30 April 1981 (Brunner and Zipfel, 1981);
- Installation Restoration Program Records Search for McClellan AFB, California (CH2M Hill, 1981);

- Final Report - Installation Restoration Program Phase II - Confirmation, McClellan AFB, California (Engineering-Science, 1983);

- Base Well Sealing Report, McClellan AFB, California (Luhdorff and Scalmanini, 1983);

- Installation Restoration Program, Phase III/IV, Site Characterization Study, Technical Memorandum No. 2 for McClellan Air Force Base, California (CH2M Hill, 1984a);

- Installation Restoration Program, Phase III/IV, Site Characterization Study, Technical Memorandum No. 3, On-Base Drilling Program and Hydrogeologic Evaluation of Area D (CH2M Hill, 1984b);

- Draft Source Control Feasibility Study for Area D, McClellan AFB, Sacramento, California (CH2M Hill, 1984c); and

- Hydrogeologic Conditions in the Vicinity of Area D, McClellan AFB, Technical Memorandum (CH2M Hill, 1984d).

Radian project staff also met with base personnel on a separate occasion. Additional information acquired during the meeting included maps of on- and off-base areas, monitor/production well locations, aerial photographs of the McClellan AFB area, and on- and off-base well sampling and boring data. The various documents and records received from the base were reviewed and posted on the Bibliographic Database.

Data acquisition efforts continued throughout the period of the study as additional information needs and sources were identified. Some of the agencies who attended the initial data acquisition meeting were recontacted to address information needs. State, federal, and local resource management agencies not in attendance at the meetings were also contacted for

identification of additional information pertinent to the study. Additional data collected included drillers' logs for the study area and hydrogeologic information and reports not already acquired.

3.2.3.2 Data Review

Following acquisition, the literature and data were reviewed. Non-site-specific data/information were compiled into a separate file set. This general information consists of summations of reviewed literature/documentation developed for this report, and text entries for wells and borings in the area of McClellan AFB. These were compiled into two "hard-copy" file sets and were entered into the General Information Database.

Information acquired for wells/borings within the present boundaries of McClellan AFB was compiled in the Site-Specific, On-Base File Set. Information collected for off-base wells and borings was incorporated into the Off-Base File Set. Combined, these file sets contain information for approximately 1300 wells in the study area. Because of the large size of the file sets (over 6000 pages), they have not been included in the distributed copies of this report. The file sets have been incorporated into a project file which is presently in Radian's possession. The file sets will be updated as studies continue and will be transferred to the USAF at a future date.

A summary of the information compiled into the on- and off-base site-specific file sets is discussed below. The methodology used for reducing information from the file sets to the computer database is described in Appendix 2B.

- On-Base Site-Specific File Set

Numerous wells and boring sites are located within the main boundaries of McClellan AFB. Wells have been installed at the base to provide water for base operations, and for ground-water quality monitoring. Several

monitoring wells were installed on base by previous investigators for determining the nature and extent of ground-water contamination in the shallow aquifer. Former private wells were also located on base by Radian and previous investigators. These wells, many of which are now abandoned, lost, or destroyed, were acquired by the base as it expanded its boundaries. Sources of information for these wells and borings along with general specifications are discussed below.

Production Wells and Former Private Well on Base

Information on the locations and specifications of production and former private wells on base was obtained from several sources. Specifications for 29 base production and former private wells were obtained from Luhdorff (1983) and Engineering-Science (1983). Four of the base production wells were located off base and beyond the limits of the study area. In certain instances, well specifications presented in Engineering-Science (1983) and Luhdorff and Scalmanini (1983) differed. Radian used professional judgment and/or input from Base Bioenvironmental and Civil Engineering personnel to ascertain correct specifications.

As noted in previous studies (Engineering-Science, 1983 and Luhdorff and Scalmanini, 1983), several of the base production wells may serve as vertical conduits for contaminant migration due to their depth and extended gravel packs. Several of the former private wells located on base may also serve as vertical conduits for contaminated ground water and/or infiltrating surface water. Of particular concern are the former private wells which are located in areas of waste disposal or industrial operations. Based on State Water Well Drillers' Reports obtained from the California Department of Water Resources, ten additional former private wells were tentatively located on base. A few of the former private wells may coincide with wells located by previous investigators. Well records were considered to represent separate wells unless sufficient evidence existed to relate records to a common well. General specifications and locations of former private and production wells

at McClellan AFB are listed in Tables 3.2-1 and 3.2-2. The locations of these wells are illustrated on Plate 5.

Water quality data for the various base production wells that could be sampled was compiled from Brunner and Zipfel (1981) and Engineering-Science (1983). Base records for the production well sampling and analysis program were also accessed. Radian commenced an on-base ground-water sampling and analysis effort on 4 September 1984 under a separate delivery order. This effort did not include the collection and analysis of samples from base production wells.

Base Monitor Wells

From the review of previous investigations and base records, it was determined that a total of 58 monitoring wells had been installed at McClellan prior to this investigation. The general specifications of the base monitor wells, installed under the three investigations (Pre-Phase II, Phase II, and Area D Phase III/IV), are discussed in Appendix 2-C. The locations of the base monitoring wells are shown on Plate 5.

Specifications, locations and water quality data for the base monitor wells were obtained from Brunner and Zipfel (1981), Engineering-Science (1983), CH2M Hill (1984a), CH2M Hill (1984b), base files and maps, and interviews with base personnel. Although a base monitor well sampling and analysis program was undertaken by Radian on September 4, 1984, these analytical data were not available as of this writing. Thus, these data have not yet been incorporated into the site-specific file set.

Waste/Soil Borings

Waste and soil investigation borings have been drilled at McClellan AFB by several investigators. Numerous soil borings have been supervised by the base in association with the Army Corps of Engineers (ACOE) for foundation, roadway and utilities construction investigations. Records of these

TABLE 3.2-1. GENERAL SPECIFICATIONS AND LOCATIONS FOR PRODUCTION WELLS AND FORMER PRIVATE WELLS AT McCLELLAN AFB, AS IDENTIFIED BY ENGINEERING-SCIENCE, 1983, AND LUHDORFF, 1983

Well No.	Date of Construction	Depth of Casing (feet)	Casing Diameter (inches)	Status	General Location
1	April 1937	400	12	Production well, out of service due to contamination	Building 231
2	April 1937	298	12	Production well, out of service due to contamination	Building 232
3	N/A	N/A	N/A	Former farm well, abandoned or destroyed	Area of Building 663
4	July 1941	382	12	Production well, used for standby irrigation only	Windstead Athletic Facility
5	-	-	-	Off-base, "Old River Dock Well"	Near the Old Garden Highway
6	N/A	N/A	N/A	Former farm well, abandoned or destroyed	Area of Building 719
7	July 1942	398	12	Production well, destroyed due to contamination, may be cemented	Area of Building 489
8	July 1942	625	12	Production well, in service	Building 91
9	July 1953	N/A	14	Collapsed production well, abandoned or destroyed	Area of Building 267
10	1945	400	14/12	Production well, in service	Building 93

(Continued)

TABLE 3.2-1. (Continued)

Well No.	Date of Construction	Depth of Casing (feet)	Casing Diameter (inches)	Status	General Location
11	1945	395	14/12	Production well, in service standby (peak demand)	Building 2100
12	N/A	390	12	Production well, out of service due to contamination	Building 395
13	1945	391	14/12	Production well, in service	Building 614
14	N/A	N/A	N/A	No information available	Unknown
15	-	-	-	- - - -	Off-base, corner of Whitney & Eastern
16	N/A	N/A	N/A	Production well abandoned	Area of Building 440
17	N/A	353	16	Production well, in service	Building 699
18	February 1953	408	14	Production well, out of service due to contamination	Building 664
19	November 1952	360	N/A	Production well, abandoned or destroyed	Area of Building 663
20	1968	600	14	Production well, standby source for Building 200	Area of Building 200
21	N/A	N/A	N/A	Former farm well abandoned or destroyed	Area of Building 696
22	N/A	N/A	N/A	Former farm well abandoned or destroyed	Area of Building 1440
23	N/A	N/A	N/A	Former farm well abandoned or destroyed	Area of Building 1457

(Continued)

TABLE 3.2-1. (Continued)

Well No.	Date of Construction	Depth of Casing (feet)	Casing Diameter (inches)	Status	General Location
24	N/A	N/A	N/A	Former farm well, abandoned or destroyed	Area of Building 1465
25	-	-	-	In service	Off-base, Lincoln Communication Site
26	-	-	-	In service	Off-base, Davis Communication Site
27	June 1962	261	6	Production well, abandoned	Rapcon Facility
28	1968	236	8	Production well, in service	Near Building 1082
29	August 1981	575	16	Production well, out of service due to excessive sand production	Building 1455

NA = Not Available.

Source: Luhdorff and Scalmanini (1983), and Engineering-Science (1983).

TABLE 3.2-2. GENERAL SPECIFICATIONS AND LOCATIONS FOR FORMER PRIVATE WELLS AT McCLELLAN AFB, AS IDENTIFIED BY RADIAN

Well No.	Date of Construction	Depth of Casing (feet)	Diameter of Casing (inches)	Status	General Location
30	July, 1947	106	6	Abandoned	Area of Building 627
31	1943	305	12	Abandoned, may be Base Production Well No. 16, as described in Luhdorff, 1983	Area of Building 440
32	April, 1961	93	6	Abandoned domestic well	Near base boundary and Monitor Well 43S
33 (a&b)	December, 1950	92	8	Abandoned irrigation well	Two possible locations from log. Location A near Waste Area 23 and Building 789, Location B near Building 680
34	August, 1950	92	6	Abandoned domestic well	Area of Building 668
35	October, 1950	85	6	Abandoned domestic well	North of Taxiway 7442 between North-South Runway and Taxiway
36	July, 1942	398	24	Possible test well for Base Production Well No. 8 (Well No. 8 noted on log but location noted different than of Base Well No. 8)	Area of Building 52
37	June, 1950	94	6	Abandoned irrigation well	North of Apron 7516
38	April, 1947	49	6	Abandoned	Below Apron 7516

(Continued)

TABLE 3.2-2. (Continued)

Well No.	Date of Construction	Depth of Casing (feet)	Diameter of Casing (inches)	Status	General Location
39	February, 1952	110	6	Abandoned domestic well, possibly Base Production Well No. 24 due to proximity	Area of Building 1438
40	November, 1950	138	6	Abandoned domestic well	Below North-South Runway south of Warm-Up Pad 7522

Source: California Department of Water Resources, Water Well Drillers' Log Files, 1984.

borings are retained at the offices of the ACOE in Sacramento, California. According to representatives of the Base Civil Engineer and the ACOE, these borings were confined to shallow soils and achieved a maximum depth of 30 to 40 feet. Because ground water occurs below the maximum depth of these borings (at about 80 to 100 feet), they do not provide information on present aquifer conditions and characteristics. Thus, these records have not been incorporated in the Site-Specific File Sets or Database.

The shallow foundation, roadway and utility borings records may, however, be useful for subsequent investigations. These records may provide information on surficial soils necessary for evaluating infiltration rates. The boring data should be reviewed for all future site characterization efforts. The method of completion (i.e., if the boring was grouted, backfilled, or left open) may play an important role in determining whether a boring constitutes a vertical pathway for contaminant migration. Also, descriptions of shallow soils may provide useful information for site characterizations.

Additional soil/waste borings on base include borings conducted under the supervision of the Base Civil Engineer for Pre-Phase II groundwater/soil contamination investigations, and borings conducted by CH2M Hill for Phase III/IV activities for Area D.

Ten soil borings were completed in Waste Areas A and B for the characterization of hydrogeologic conditions during the Pre-Phase II groundwater investigation program conducted by the base between September and November 1980 (Brunner and Zipfel, 1981). Five of these borings were completed as monitor wells and have been assimilated into the On-Base Site-Specific File Set. Four of the remaining borings were extended to a depth of approximately 120 feet. The fifth soil boring only extended to a depth of a few feet, due to an obstruction encountered during drilling. The four base borings not completed as monitor wells extend to the present depth of the shallow aquifer. Thus, they provide information on characteristics of the

shallow ground-water system and have been incorporated into the Site-Specific File Set and Database.

From a review of the boring records and logs, the method used for the abandonment of these soil borings (not completed as wells) is not presently known. If the borings were left open (below a surface cap) or backfilled with permeable materials, they may provide a vertical pathway for contaminant migration. The method used for completing these borings is of particular concern because they are located in an area of industrial activity.

Numerous soil/waste borings were drilled in the vicinity of Waste Area D for the characterization of site conditions for Phase III/IV of the McClellan AFB IRP (CH2M Hill, 1984a). These borings were not extended to ground water due to environmental concerns and thus do not provide information on the characteristics of the shallow aquifer system. These borings have not been incorporated into the Site-Specific Database.

Off-Base Site-Specific File Set and Database

Over 1000 private and public wells are known to exist in the off-base portion of the project study area. The general types of information obtained for the investigation are discussed below.

Private Wells

As discussed in Section 3.3 of this report, Radian conducted a door-to-door well inventory to obtain information on private wells located in the off-base portion of the study area. Information provided by this survey was compiled onto survey forms and notebooks maintained by field personnel. At the completion of the survey, forms for residences having wells were compiled in the Site-Specific Off-Base File Set. These file sets have been organized by street, with individual addresses assembled in ascending numeric order.

Information from the well inventory was supplemented with water quality data obtained from the CRWQB,CVR and summarized water quality data provided by McClellan AFB personnel. These data were developed as the result of the off-base water well sampling effort undertaken by the CRWQB in association with the County of Sacramento and McClellan AFB. This program is currently being conducted as a continuing effort to determine the impact of ground-water contamination on private wells in the area of McClellan AFB. At the time that the site-specific data acquisition efforts were initiated, the most recent quarterly analysis set available (Winter of 1984) was incorporated into the database.

Over 100 private water wells have been sampled and analyzed for the CRWQB off-base sampling effort. Analysis conducted under this program mainly consists of EPA Method 601 for volatile organics. Analyses for pesticides, trace metals, polychlorinated biphenyls and EPA 624/625 parameters have been conducted for the off-base wells on a limited basis.

In addition to the analytical data from the off-base well sampling program, sampling operation field notes from that program were also incorporated into the file sets. The field notes describe the date, method, and type of sample collected. The field notes sometimes also describe general well specifications and sampling points. For the most part, each set of analyses was matched with field sampling notes. In a few instances, analytical data and sampling notes could not be matched. This discrepancy may indicate that a small portion of the data for the off-base sampling effort is missing from the file set. Radian has assumed that all available off-base water quality data generated by the sampling program have been made available through the records of the CRWQB,CVR and McClellan AFB.

Specifications for private wells in the off-base portion of the study area were also obtained from a well survey conducted by the CRWQB for an area southwest of the base (CRWQB, 1984). Information developed in this survey included well location, depth, diameter and water use for wells within the surveyed area.

Water well drillers' logs obtained from the California Department of Water Resources (CDWR) (CDWR, 1984) provided another source for specifications of private wells in the off-base portion of the study area. Several of the drillers' logs obtained for the study area did not include sufficient information such that well locations could be determined. These logs have been incorporated in an addendum to the Off-Base Site-Specific File Set.

From a review of drillers' logs for wells in the off-base portion of the study area, it appears that the majority of private wells (for which information was available) are completed within the shallowest water-bearing zone. A common method of completion for area private wells is "open hole." Normally, this completion method consists of leaving the borehole uncased or open below the water table to serve as the zone of production. Above the open portion of the well, the wellbore is often cased with steel pipe. The bottom of the casing is usually seated in a layer of clayey material just above the open portion of the hole. The pump for this type of well is often positioned at the lowest point of the well casing.

Numerous abandoned private wells exist in the off-base portion of the study area. Well abandonment probably occurred as water levels declined due to regional overproduction. In some instances, well owners chose to deepen existing wells to keep pace with the declining levels. Other wells, which were abandoned, may pose a significant safety and environmental hazard if they are not properly capped and sealed.

Municipal/Public Wells

Information on municipal/public wells in the general study area was obtained from the following organizations.

City of Sacramento
California Transportation Authority (CalTrans)
Arcade Water District
Northridge Water District
Rio Linda Water District

Municipal/public well locations are illustrated in Figure 3.2-1 and Plate 5.

The City of Sacramento presently operates several production wells in the area of McClellan AFB. Although some of these are located beyond the study area boundary, they have been included in the Off-Base Site-Specific File Set because they contribute to drawdown in the area of the base.

Specifications for the Sacramento City wells were obtained from drillers' logs and completion records obtained from city records. Water-quality data were available for several wells, including analysis for volatile organic compounds. These data are included in the file set.

City of Sacramento production wells in the area of McClellan AFB produce water for municipal supply and irrigation. Two wells in the area of McClellan AFB, Wells CW150 and CW154, have been affected by organic compounds. City Well 150 has been shut down due to the presence of trichloroethylene (TCE) and now serves as an emergency supply source.

Records obtained from CalTrans indicate that CalTrans operates four irrigation wells that are located in the southern portion of the study area. These wells are located along Interstate 80 and Business 80 as shown in Figure 3.2-1. According to CalTrans, Marysville District, these wells are

used exclusively for freeway landscape irrigation. No water quality or construction information was available for these wells.

Arcade Water District presently operates one municipal supply well in the northeast section of the study area, as shown in Figure 3.2-1. The district also operates four production wells, south of the base along Auburn Boulevard and three wells east of the base, north of Ascot Avenue. Although the wells south of Auburn and the wells east of the base (Watt Avenue) are beyond the limits of the study area, they have been included in the file sets and database due to their size, locations, and use.

Specifications for the Arcade Water District wells were obtained from drilling and completion records collected from district files. Results of specific capacity/pump efficiency and chemical tests were also collected and assimilated into the database.

Rio Linda Water District has no wells within the study area. Two of the district's production wells were identified just outside of the study area, as shown in Figure 3.2-1. These wells were incorporated into the site-specific database because of their size and use. Information on the specifications of the two Rio Linda Water District wells was obtained from drillers' logs and specific capacity/pumping efficiency test records obtained from district files. Chemical analysis results were also collected.

Northridge Water District, which is located east and southeast of McClellan AFB, operates several municipal production wells. These wells are generally located upgradient from the base. Only one Northridge District well is located in the study area as shown in Figure 3.2-1. Specifications and water quality data were collected for this well.

Borings

Off-base soil boring operations were conducted by CH2M Hill and Radian for determining the nature and extent of off-base soil/ground-water

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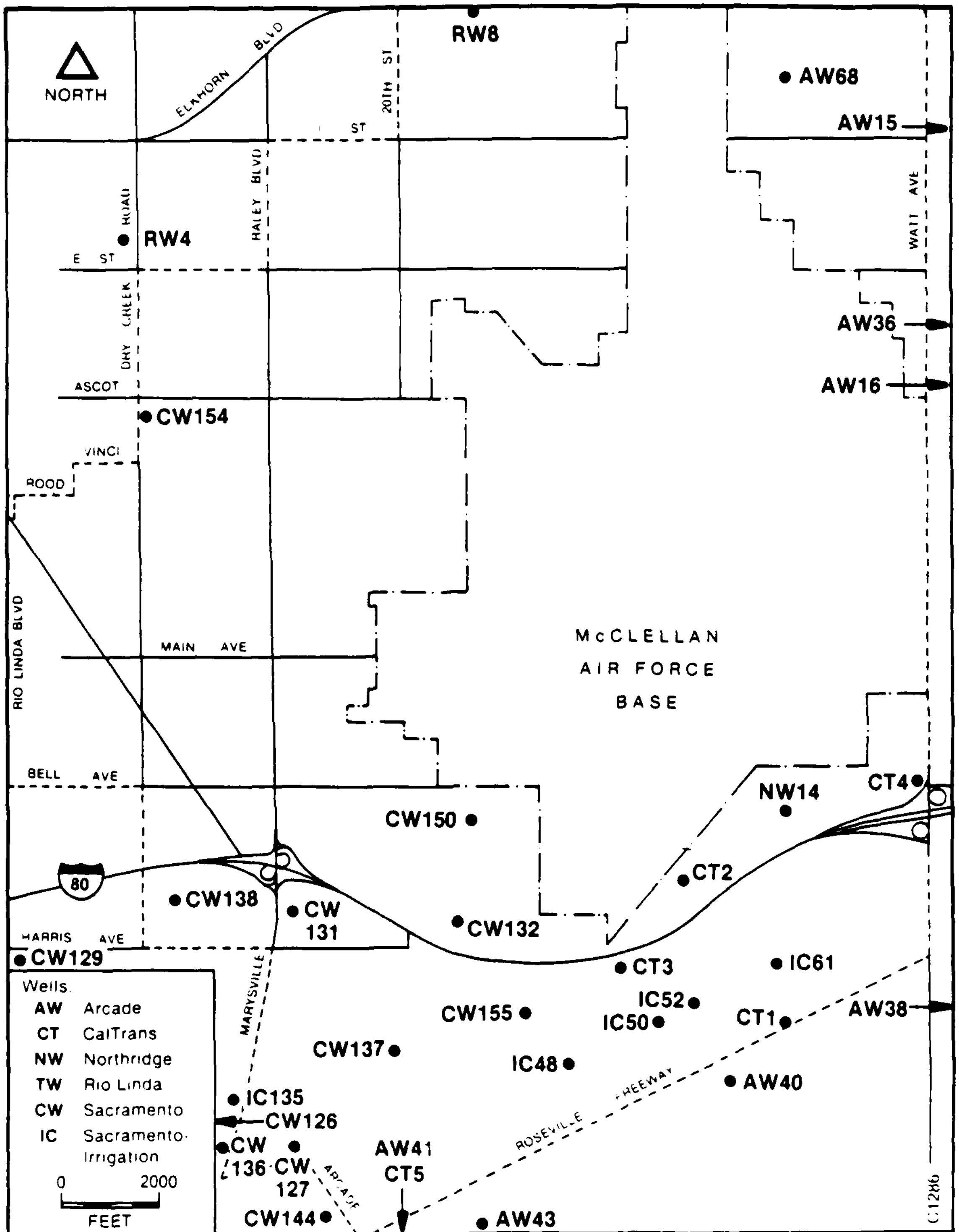

Figure 3.2-1. Location of Municipal Wells in or Near Study Area

contamination. Ten off-base soil borings were performed by CH2M Hill during March and April, 1984 (CH2M Hill, 1984e). These borings were limited to a relatively small area in the vicinity of waste Area D immediately outside the installation boundary. The soil borings were extended to a depth of approximately 70 feet for the collection of soil samples. The soil borings were not extended to ground water and thus they have not been included in the Site-Specific File Set.

Radian completed 29 off-base reconnaissance borings during this investigation. The reconnaissance borings were extended to depths of approximately 200 feet for the evaluation of hydrogeologic conditions in areas around McClellan AFB. Data from the reconnaissance borings were incorporated in the Site-Specific Data File Set. The methodology and findings of the reconnaissance boring effort are discussed in Section 3.5.

3.2.4 Conclusions

As the result of data review efforts for this study, environmental information for the McClellan AFB area was collected, reviewed and assimilated into "hardcopy" file sets and computer databases. Data for approximately 1300 wells in the area of McClellan AFB were collected and assimilated into site-specific file sets and databases. Non-site-specific data, such as that obtained from the literature, were incorporated into the Non-Site-Specific File Set.

Data from the file sets and databases were used in the various tasks for this study. During data review efforts, several on-base monitoring wells, former private wells, and borings were identified as possibly providing vertical pathways for contaminant migration (in addition to wells identified by Engineering-Science (1983) and Luhdorff and Scalmanini (1981). It was also noted that numerous abandoned wells exist off base. Many of these wells could pose a significant environmental and/or safety hazard if they were not abandoned according to accepted practices.

The file sets and databases provide an organized, comprehensive source for the relatively large amount of environmental information available for the McClellan AFB area. Data contained in the computer databases can be readily accessed and reduced using database system access/manipulation routines and CPS (Contour Plotting System). The file sets and databases will also provide information for subsequent investigations. On-going file and database updating and maintenance efforts are required in future efforts to ensure that information available from the databases are comprehensive and up-to-date.

3.3 Task 3 - Well Inventory

A comprehensive water well survey was conducted in an area of interest surrounding McClellan AFB. This study area is the off-base area where potential ground-water impacts associated with on-base waste disposal would be most likely to occur as well as the 'background' area to the northeast of the base. The study area includes the zone of land located within approximately one mile of the McClellan AFB boundary in the general direction of ground-water flow (Figure 3.3-1). The area is primarily residential with some agricultural and commercial land use. The northern part of the area of interest is dominantly rural with private wells providing the sole source of water for all uses. The southern part of the area is primarily urban and suburban. Large sections have been supplied with City water since the late 1950s or early 1960s. However, abandoned private wells which formerly provided water prior to the City hook-ups exist throughout the area. In the following subsections, the objectives, approach, results, and conclusions of the well inventory are presented.

3.3.1 Objectives

The overall objective of the well survey was to identify as many of the existing wells as possible in an area of interest surrounding McClellan AFB (Figure 3.3-1). In addition, all on-base wells were located and entered into the project database. The purpose of inventorying the existing wells was to identify areas of predominant private well use versus city water use, to characterize the aquifer zones most commonly tapped by wells, to identify well usage, and to determine which wells, if any, might be suitable for use in a ground-water monitoring program.

3.3.2 Approach

The first step in conducting the comprehensive well survey was to review the hydrogeologic data assembled in Task 2 (Data Review). The information contained in the database was helpful in designing the well survey

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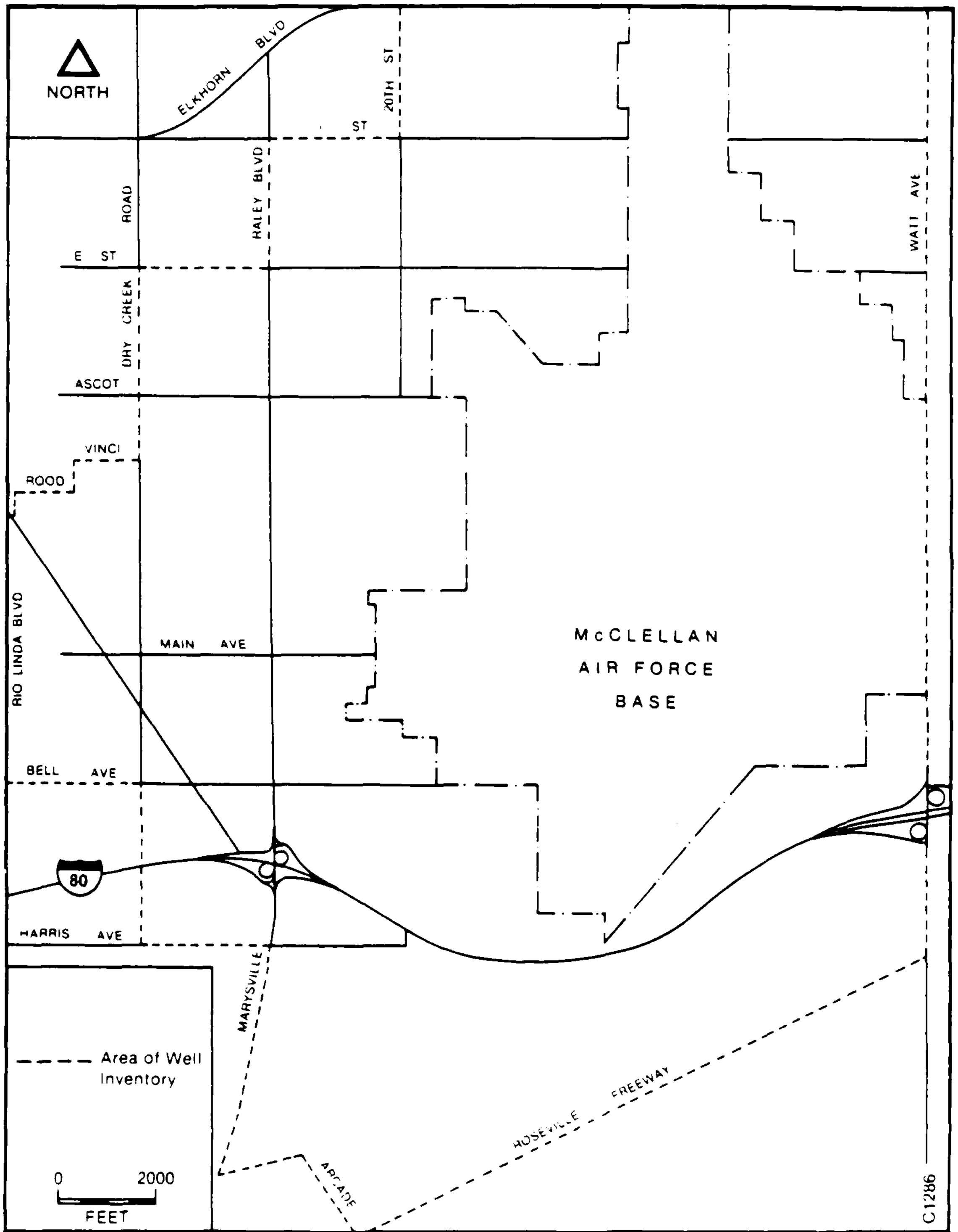

Figure 3.3-1. Area of Well Inventory

form. Questions included on the form pertain to well existence, ownership, use, and construction as well as to any suspected or known ground-water quality problems. The form also provides an indication of the property owner's willingness to participate in any future ground-water monitoring program. Figure 3.3-2(A,B) is a copy of the well survey questionnaire.

A second form was also distributed by the field survey team. This form (Figure 3.3-3) is a release authorizing Radian to include any pertinent information regarding private wells (e.g., well drillers' logs, ground-water quality analyses, etc.) obtained from city, county, or state records in the final project report. Authorization could only be granted by the property owner or his/her legal representative and is shown by his/her signature.

Two attempts were made to contact residents in the area of concern regarding the potential existence of active or abandoned wells on their property. During the five-week period from 29 May through 29 June 1984, two teams of two-persons each conducted an initial round of door-to-door canvassing of the neighborhoods. When a resident was contacted, the questions on the form were asked by a member of the survey team and the form was filled out and signed by the resident. All field team members carried appropriate identification. The reverse side of the survey form provided a written explanation of the purpose of the well survey. Further verbal explanation of the survey intent was provided by team members if requested by the resident.

At locations where individuals could not be contacted, a survey form was left, usually secured in the door jamb. The forms were self-addressed and had a return postage paid permit. They also carried a request that the form be completed and returned to Radian within one week. During the first round of the survey, 3035 forms were either completed or left at residences.

At all addresses where active and/or inactive wells were identified, their locations were recorded in field notebooks carried by the project team. Locations were measured by tape from the nearest mappable features; most

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Please answer the following questions as accurately as possible. If you do not know an answer, leave it blank. Thank you for your cooperation.

Well Survey

Name: ______________________________

Address: ______________________________

Telephone: ______________________________

1. Are you the property owner at this address? ☐ Yes ☐ No
   If not, who is the property owner? ______________________________
   Name
   ____
   Address

2. Are there one or more well(s) at this address? ☐ Yes ☐ No
   How many? ______________________________
   (If there is not a well at this address, please return form with above information.)

3. How is the well at this address used?

   ☐ Drinking Supply ☐ Commercial (non-drinking) ☐ Monitoring Well
   ☐ Irrigation ☐ Municipal Supply ☐ Not used

4. How deep is the well? ______________________________ feet

5. When was the well drilled? ______________________________

6. What is the well diameter? ______________________________ inches

7. What is the depth to water when *not* pumping? ______________________________ feet

8. What is the pumping rate of the well? ______________________________ gallons per minute

9. What are the depths to the top and bottom of the well screen (where water comes into the well?) top: ____ feet; bottom: ____ feet

10. Have there been any problems with the well water? ☐ Yes ☐ No
    If yes, describe. ______________________________

11. Has the water been sampled for laboratory analysis? ☐ Yes ☐ No
    If yes, when was it sampled? ______________________ By whom? ______________________

    Do you have a copy of the results? Yes No

12. If needed, may we collect a water sample for analysis (no cost to you) and measure the depth to water? Yes No
    If yes, we will contact you to arrange for access. No one will enter your property or sample the well without your permission.

    Please sign and date.

______________________________ ______________________________
Signature Date

Please, fold, seal, and return by mail (no postage necessary) within one week.

Figure 3.3-2a. Well Inventory Questionnaire (side one)

RADIAN CORPORATION

IMPORTANT
REQUEST FOR ENVIRONMENTAL INFORMATION
PLEASE DO NOT DISCARD

FOLD HERE

BUSINESS REPLY MAIL

FIRST CLASS PERM. NUMBER SACRAMENTO, CA

POSTAGE WILL BE PAID BY—

RADIAN CORPORATION

Attn Mr Wayne Pearce
3401 La Grande Blvd
Sacramento CA 95823

NO POSTAGE NECESSARY IF MAILED IN THE U.S.

FOLD HERE

IMPORTANT - Please Read.

The U.S. Air Force, McClellan Air Force Base has contracted with Radian Corporation to perform an environmental study of ground-water quality in this area. As part of the study, it is necessary to know as much as possible about the location, use and depth of water wells in the area. Please answer the questions on the other side of this form and return by mail (no postage necessary) within one week.

If you have any questions, call: Mr. Wayne Pearce
Radian Corporation
421-8700

Figure 3.3-2b. Well Inventory Questionnaire (side two)

RADIAN CORPORATION

IF DRILLERS' DESCRIPTIONS OF ALL/ANY WELLS ON THIS PROPERTY ARE AVAILABLE FROM THE CALIFORNIA DEPARTMENT OF WATER RESOURCES, I HEREBY GRANT PERMISSION TO RADIAN CORPORATION TO USE THIS INFORMATION FOR THE ENVIRONMENTAL STUDY BEING PERFORMED BY RADIAN. I UNDERSTAND THAT I MUST BE THE PROPERTY OWNER OR HIS/HER LEGAL REPRESENTATIVE TO GRANT APPROVAL.

____________________ SIGNATURE

__________ DATE

__________________________________ ADDRESS

Figure 3.3-3. Drillers' Log Release Form

often, road intersections. The field locations were subsequently converted to computer grid coordinates and entered into the project database.

For all addresses where a form had been left but not returned within two weeks of the first attempted contact, a second form was mailed out. During this second phase of the survey, 1,280 questionnaires were distributed.

3.3.3 Results

Of the 3,035 residences included in the field canvassing effort (Round 1), 1,755 forms were completed by the field crews or returned by the residents. During this round, 890 wells were identified. In the second phase of the well inventory, 1,280 questionnaires were mailed out to those addressees not contacted or responding to the field survey. An additional 135 completed forms, identifying 41 more wells, were returned.

The overall response rate to the well inventory was approximately 62 percent. In all, 1,279 wells were identified in the survey area. The breakdown of wells by use is provided in Table 3.3-1 and is illustrated on Plate 3. Appendix 3A provides a well status summary with addresses for residences and businesses where wells were identified.

Throughout the field survey, in addition to identifying wells, team members noted a number of off-base privately-owned operations that could potentially contribute to ground-water pollution due to the nature of materials routinely handled. Examples include a generator shop, auto repair and gasoline service stations. Also, wastes from a poultry farm located within the study area were observed being discharged directly into a creek which crosses the property and an abandoned private well was identified which was being used to dispose of waste oils and degreasing fluids.

TABLE 3.3-1. SUMMARY OF ALL WELLS IDENTIFIED IN THE COMPREHENSIVE WELL SURVEY (TASK 3), BY WELL USE

Principal Use Category	Number of Wells
Drinking Supply (Private)	403
Irrigation	25
Commercial/Industrial	2
Municipal Supply	32
Ground-water Monitoring	67
Subtotal - Active Wells	529
Not Used (Abandoned)	593
Use Unknown	157
Total - Active and Inactive Wells	1,279

3.3.4 Conclusions

The Well Inventory task provided a large amount of data important to the characterization and assessment of ground-water conditions in the vicinity of McClellan AFB. It is anticipated that the inventory results will prove very valuable in future stages of the IRP effort.

The response rate of over 62 percent is considered exceptional for a door-to-door and mail-out survey. It reflects the general concern and awareness of local residents toward ground-water conditions.

Uncertainties remain concerning the extent to which improperly abandoned wells located on private property may contribute to potential ground-water contamination, either through misuse or neglect. A number of unsealed abandoned wells were observed. Such wells could act as conduits for migration of contaminants to the ground-water system. In one case, a resident

actually showed the survey team an open well casing filled with waste oil he was disposing. The extent to which such practices occur is largely unknown, as most individuals would be unlikely to identify any wells they were knowingly misusing. The well inventory does, however, demonstrate that McClellan AFB is not the sole potential source of ground-water contaminants within the study area.

The results of the well survey also show that few of the privately-owned wells would be suitable for inclusion in a ground-water monitoring network. In most cases, the owner's knowledge of well construction, depth to water-producing zone(s), etc., was found to be very limited. Likewise, existing drilling records are generally reported in insufficient detail to provide the kind of information needed in devising a monitoring program. Finally, most of the wells are equipped with dedicated submersible pumps and are connected to holding tanks. This kind of delivery system is poorly suited to the collection of representative water samples on a routine basis as it does not allow easy access to the water column.

3.4 Task 4 - Geologic Investigation Planning

3.4.1 Objective

The objective of the Geologic Investigation Planning task was to formulate a plan to determine the geologic/hydrologic setting in areas surrounding the base. It had been predetermined that some off-base drilling would be necessary in order to define the geologic units and saturated zones. The geologic planning task selected an appropriate drilling/sampling method and the locations of the drilling (reconnaissance borings).

3.4.2 Approach

The following steps were implemented in developing the geologic investigation plan:

- Data requirements were reviewed and a sampling and analysis plan was formulated,

- Available drilling methods were assessed with respect to the ability to identify geologic units during drilling, to identify saturated zones during drilling, to provide an appropriate means of obtaining water samples from specific saturated zones, and accomplish the required work in a suitable time frame,

- Information was assessed regarding the status of contamination and the need for additional information in some areas. This assessment included the results of the Data Review (Task 2) and the Well Inventory (Task 3). From this information assessment, the locations of the reconnaissance borings were selected,

- The recommended drilling locations were presented to the Air Force and agencies, and

- The geologic investigation plan was then modified to incorporate agency requests.

3.4.3 Results

It was determined that several data requirements were of prime importance in the geologic investigation. These requirements were:

- Geologic units encountered must be accurately defined during drilling. In order to accomplish this, material being removed from the drill-hole (called 'cuttings') must be brought to the surface in such a manner that accurate geologic logging can be conducted.

- Saturated zones must be accurately identified during drilling.

- Water samples must be collected from each saturated zone for water-quality analysis. The samples must be representative of each zone without cross-contamination or the addition or removal of chemical species of concern.

- Water samples collected should be analyzed for primary anions and cations (calcium, magnesium, sodium, carbonate, bicarbonate, sulfate, and chloride), plus iron, in order to distinguish natural water quality variations and, thereby, hydraulically separated zones.

- Water samples should also be analyzed for volatile organic compounds by EPA Method 601. This will provide a preliminary indication of the presence of contaminants, but is not intended to provide quantitative data on potential organic contaminant concentrations. Because the Method 601 analysis of grab water samples will be used only as a screening tool, negative results will not be interpreted as unequivocal evidence of no contamination.

- o Soils from saturated zones must be sampled and analyzed for grain-size distribution in order to select the proper well-screen slot sizes for future monitoring wells.

- o Borings should be drilled to a depth which encompasses all contamination impacted zones. This was originally believed to be 150 ft. deep, but data collected in Area D prior to the initiation of reconnaissance boring drilling indicated some contaminants were observed at 150 ft. below land surface. It was therefore decided to extend the borings to a depth of 200 ft.

The drilling method selected for the reconnaissance borings was dual-tube, air rotary drilling, based primarily on its ability to fulfill the main task objective of hydrogeologic characterization. This method utilizes a double-walled drill pipe (dual tube) and lifts the cutting by compressed air. As required, small volumes of water may be injected to aid in penetration of hard strata and to lift cuttings. The compressed air is circulated down the annulus between the inner and outer pipes to a drill bit where its flushes the cutting up through the center tube at high velocity (approximately 7,000 feet per minute). The rapid flow of chips and formational water are passed into a centrifugal separator (cyclone) mounted on the rig, from which samples are easily collected.

Because the outer tube supports the hole and circulation is primarily maintained internally (compressed air is not blown into the formation), surface casing can be eliminated.

> "This results in one of the system's prime advantages - the ability to maintain circulation even while drilling in caving or unconsolidated strata, voids, or highly fractured ground. Using proper drilling and sampling techniques, cuttings and water samples from dual-tube drilling are not contaminated by wall erosion, are free

of foreign matter, and therefore are highly representative of the strata encountered." (California Geology, 1981).

Figure 3.4-1 is a schematic diagram of the dual-tube drilling system and Figure 3.4-2 shows the path of air circulation near the bit.

After reviewing existing data (Task 2) and the results of the well inventory (Task 3), locations for reconnaissance borings were selected. The delivery order specified that a maximum of 20 borings were to be drilled. The selected locations for these borings are shown in Figure 3.4-3 and Plate 5 as points RB-1 through RB-20. Table 3.4-1 list the rationale for selection of these locations.

The proposed locations of the 20 borings were presented to McClellan personnel and agency representatives. The agency representatives suggested that additional borings were needed and that all borings should be drilled to 200 ft. instead of the proposed 150 ft. depth. Although the contract modification required to accommodate the agency request caused a 5 week project delay, the Air Force agreed to the requests. The additional borings are shown in Figure 3.4-3 and Plate 5 as RB-21 through RB-29.

Correspondence from the California Regional Water Quality Control Board regarding additional borings is given in Appendix 4A.

3.4.4 Conclusions

It is concluded that the Geologic Investigation Planning task accomplished the stated objectives by deriving a plan to define the geology and hydrology near McClellan AFB.

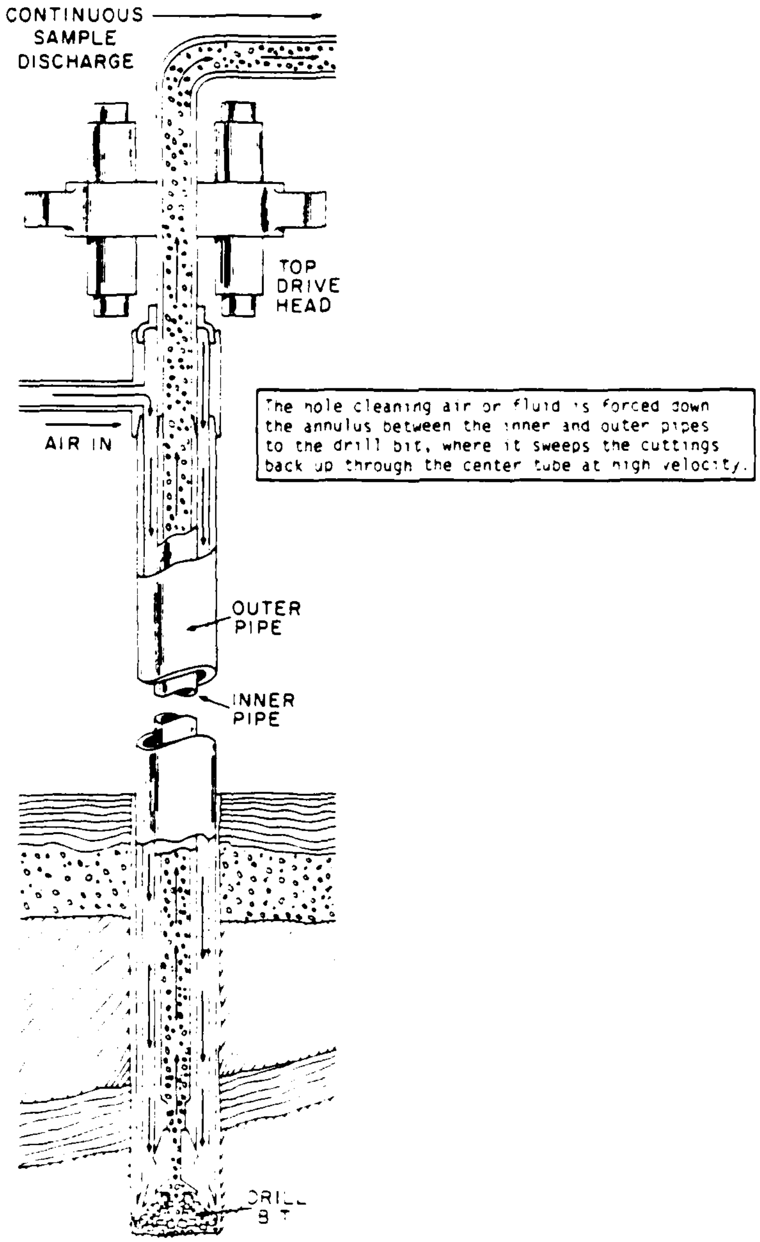

Figure 3.4-1. Schematic Diagram of Dual-Tube Air Rotary System

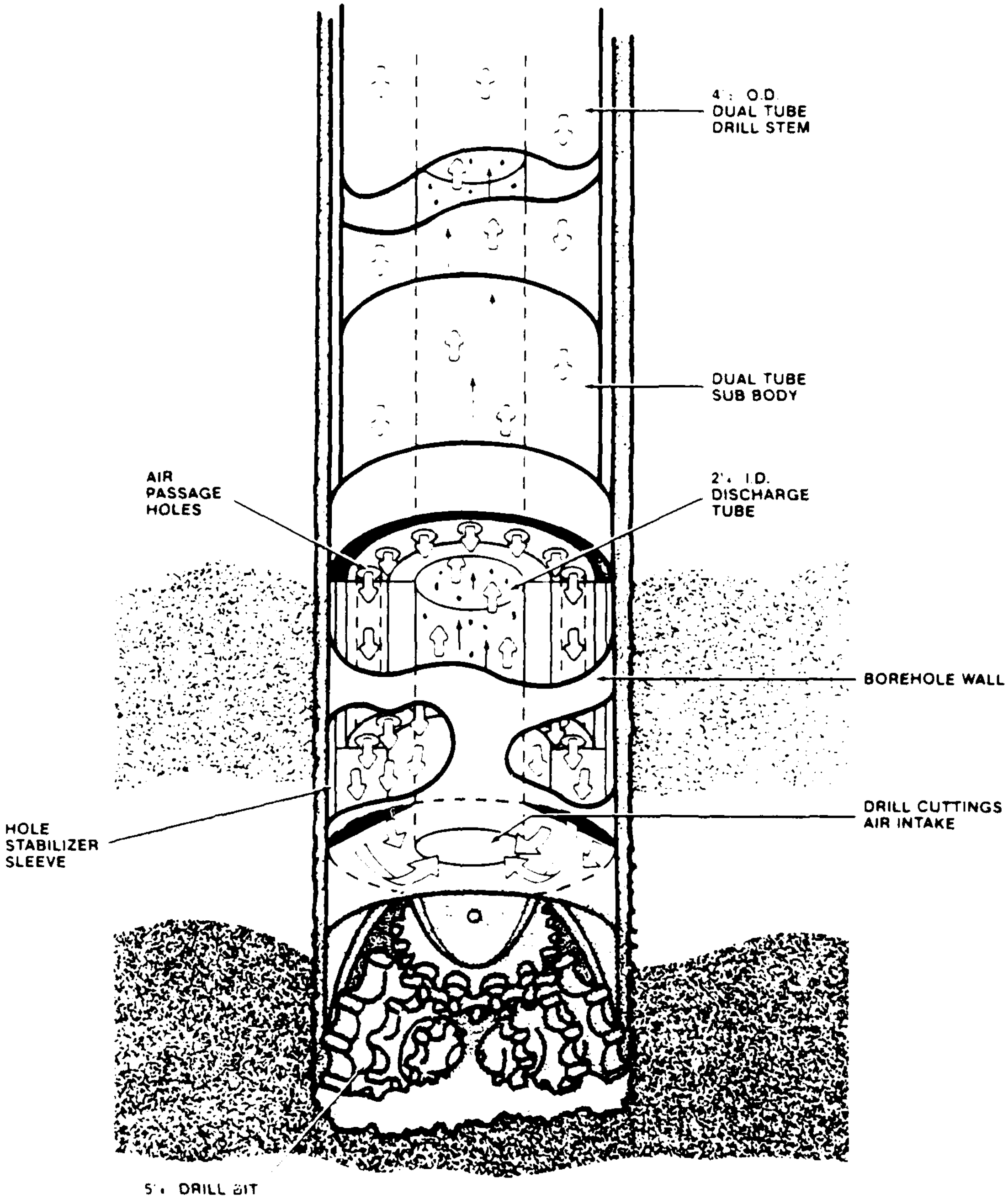

Figure 3.4-2. Schematic Diagram of Dual-Tube Air Circulation near the Drill Bit

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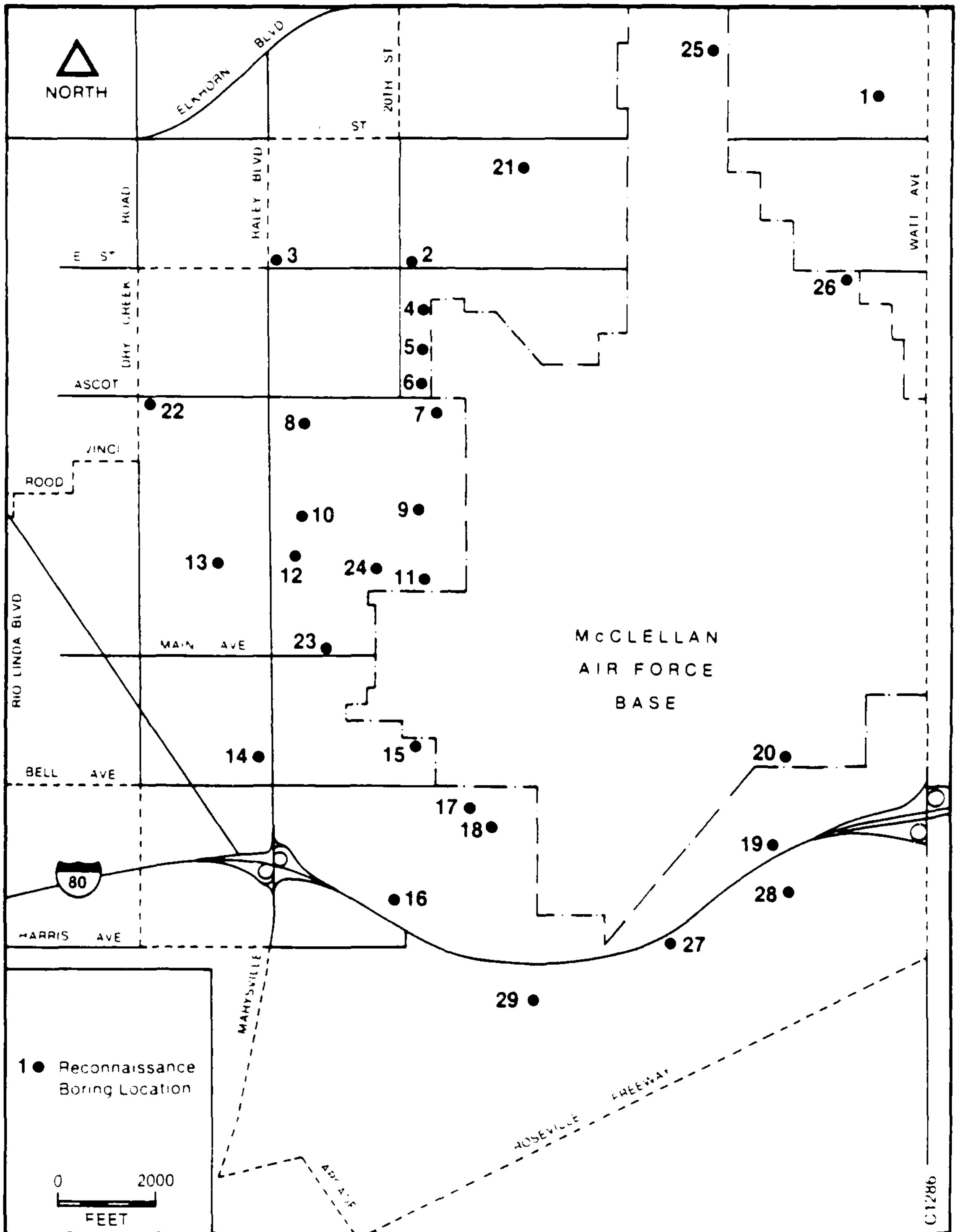

Figure 3.4-3. Locations of Reconnaissance Borings

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TABLE 3.4-1. RATIONALE FOR RECONNAISSANCE BORING LOCATIONS

Boring Number	Location Rationale*
RB-1	Background Boring - Upgradient of Base
RB-2	Northwest of Area D in vicinity of impacted wells
RB-3	Near Rio Linda Creek - Northwest of impacted area
RB-4	Near Area D - in area of impacted wells
RB-5	Near Area D - in area of impacted wells
RB-6	Near Area D - in area of impacted wells
RB-7	Southwest of Area D - Assumed downgradient of Area D
RB-8	Define geology/hydrology in vacant lot area
RB-9	Define geology/hydrology in vacant lot area
RB-10	Define geology/hydrology in vacant lot area
RB-11	Define geology/hydrology in vacant lot area
RB-12	Define geology/hydrology in vacant lot area
RB-13	In area of impacted wells near Santa Ana Avenue
RB-14	Define geology/hydrology southwest of base
RB-15	Located between base and impacted wells
RB-16	Define geology/hydrology southwest of base
RB-17	Located between base and City Well CW 150
RB-18	Located between abandoned well used for oil and solvent disposal and CW 150
RB-19	Located between Area A and City Well to south
RB-20	Located between Area A and City Well to south
RB-21	Agency request (See Appendix 4-A, ¶1.a.)
RB-22	Agency request (See Appendix 4-A, ¶1.b.)
RB-23	Agency request (See Appendix 4-A, ¶1.c.)
RB-24	Agency request (See Appendix 4-A, ¶1.d.)
RB-25	Agency request (See Appendix 4-A, ¶1.e.)
RB-26	Agency request (See Appendix 4-A, ¶1.e.)
RB-27	Agency request (See Appendix 4-A, ¶1.d.)

(Continued)

TABLE 3.4-1. (Continued)

Boring Number	Location Rationale*
RB-28	Agency request (See Appendix 4-A, ¶1.d.)
RB-29	Agency request (See Appendis 4-A, ¶1.d.)

*Note: The rationale for all boring locations is to define the geology/hydrology in the area. Comments shown as 'Location Rationale' address special considerations in location selection.

AD-A156 282 INSTALLATION RESTORATION PROGRAM PHASE II (STAGE 2-1) 2/3
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F33615-83-D-4001

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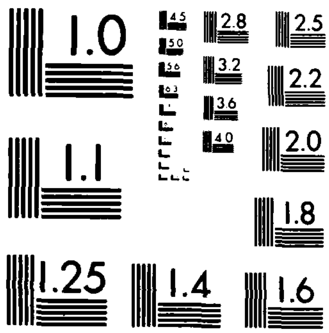

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3.5 Task Five: Reconnaissance Borings

3.5.1 Objectives

The emplacement of reconnaissance borings in the vicinity of McClellan AFB was conducted to meet several objectives. These objectives were:

- To further define the geologic units present from the land surface to 200 ft below land surface, especially in suspected contamination areas,

- To identify saturated zones (aquifers) and determine if these zones are laterally continuous,

- To sample saturated zone soils and determine the grain-size distribution of the samples. By this analysis, appropriate monitor well screens can be selected for future well installations,

- To obtain water samples from each saturated zone and determine the temperature, pH, conductivity, and major anion/cation concentrations. These analyses assist in identifying hydraulically separated saturated zones, and

- To analyze the water samples for volatile organics by EPA Method 601. This serves as a screening analysis for identification of contaminated areas.

3.5.2 Approach

The approach to the emplacement of the 29 reconnaissance borings is divided into 3 stages: pre-drilling activities, drilling activities, and post-drilling activities. These are discussed in the following sections.

3.5.2.1 Pre-Drilling Activities

Reconnaissance boring locations were selected to meet certain data requirements (Section 3.4). The locations occurred on private properties, on public right-of-ways, and on McClellan AFB. For all locations on private property, Radian obtained access permission from land owners. Figure 3.5-1 is an example of the Entry Agreement Form used. While most of the land owners contacted granted access permission, some land owners refused. When this occurred, an alternate, nearby drilling location was selected.

For borings located on public right-of-ways, Radian applied for and received an encroachment permit from the City of Sacramento. A copy of this permit is given in Appendix 5-A. Boring locations on McClellan AFB were approved through normal Air Force channels.

Drilling of the reconnaissance borings also required a County Health Department Permit. This was applied for and received prior to drilling. A copy of this permit is given in Appendix 5-B.

Arrangements were made with McClellan AFB personnel to dispose of all soil cuttings removed from the reconnaissance borings. It was planned that all cuttings would be contained in drums, that the drums would be monitored for volatile organic compounds using photoionization detectors (PID), and that all cuttings showing little or no volatile organics would be dumped, on base, as clean fill. Any drums with greater than 50 ppm total volatile organics (based on PID monitoring at the soil surface in an open drum) would be sealed and stored for laboratory analysis before selecting a

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ENTRY AGREEMENT

Radian Corporation is under contract to the United States Government (Department of the Air Force, Contract Number F33615-83-D-4001, Delivery Order 0016) to conduct Phase II (Stage 2-1) of the Installation Restoration Program at McClellan AFB, California. In performance of this work, it is necessary for Radian Corporation and/or its subcontractor(s) to drill reconnaissance (exploratory) soil borings at various sites outside the boundaries of McClellan AFB.

In consideration of Radian Corporation being provided access to and permission to drill on the following property/address:

All property owned by:
Peter J. Garrette
(west of McClellan AFB)
(description/location of property)

(hereafter referred to as "Premises") by

Peter J. Garrette
(Name of property owner)

(hereafter referred to as "Owner"), Radian Corporation hereby agrees as follows:

1) To enter premises only on the date(s) indicated at "Access date(s)" and solely for the purpose defined above;
2) To limit the number of persons on the Premises to the minimum required to accomplish the work;
3) To assume responsibility for all subcontractor(s) and subcontractor employees; and
4) To clean up the work area immediately upon completion of the drilling work and return the Premises to as good condition as prior to entry upon the Premises at no cost to the Owner.

Owner, on behalf of itself and any occupants of the Premises on the "Access date(s)", and Radian Corporation hereby agree to hold each other harmless from and against any claim, cause of action, liability, cost or expense, including reasonable attorneys fees, for bodily injury, death or property damage to itself (and, for Radian Corporation, and of its subcontractors) which either party may incur or which may be asserted against either party in connection with this Agreement, except in any case in which the cost, expense, damage, injury or death is caused by the sole negligence or willful misconduct of the other party.

Access Date(s): 30 July - 7 September, 1984

Owner:	Radian Corporation
Peter J. Garrette (Signature)	E. Wayne Pearce (Signature)
Peter J. Garrette (Type or Print Name)	E. Wayne Pearce (Name)
24 July 1984 Date	24 July 1984 Date

Figure 3.5-1. Example of Property Access Agreement

disposal method. Because all reconnaissance borings were to be drilled in areas free from waste disposal, no significant source of contaminants was expected, in soil cuttings, other than those contaminants in the ground water.

Prior to drilling each reconnaissance boring, an exact drilling location was selected (in cooperation with land owners on private property), checked for possible underground utilities, and scanned with a Fisher Model TW-5 Pipe and Cable Locater.

3.5.2.2 Drilling Activities

Drilling activities commenced on July 23, 1984 and were completed on September 6, 1984, one day ahead of schedule.

Drilling was conducted with dual tube air rotary rigs utilizing a 5 1/8-inch tri-cone bit and 4 1/2 O.D. drill stem. No drilling additives were used during drilling so as not to introduce any contaminated fluids. The drill pipe threads were lubricated with a Teflon™ paste thread sealing compound that was approved by Radian before the commencement of the field activities. Occasionally, strata were encountered which could not be penetrated using air alone. Typically, such units consist of hard, dry, very fine silts and clays. In instances where drilling had continued for approximately 5 to 10 minutes with no progress, small volumes of water were injected episodically. The water served the dual purpose of aiding in advancing the bit through the hard zones and in returning formation cuttings that would otherwise not be recovered in continuous sequence. Since the main objective of the reconnaissance borings was to characterize the hydrogeologic environment, obtaining continuous cuttings received primary attention. Furthermore, only potable water was injected into these non-water-bearing zones at a low rate (1-2 gpm) for minimal periods of time. Therefore, the incidental use of water is not considered significant.

The formation cuttings were discharged through a cyclonic separator directly into 55 gallon drums. Formation samples were collected from the cyclone and composited over five foot intervals throughout the entire boring. These samples were placed in plastic bags for visual examination. Radian geologists compiled drilling logs for each boring. These logs are given in Appendix 5-C.

Selected formation samples from saturated zones encountered during drilling were analyzed for grain-size distribution by a subcontracted laboratory. These analyses were performed to aid in correlating geologic units and to provide an indication of the appropriate slot-size for well screens in monitoring wells, to be installed. Results of the grain-size analyses are given in Appendix 5-D.

The bagged samples were also screened with a PID organic vapor analyzer in order to detect the presence of volatile organic contaminant vapors. The volatile organic levels were recorded on the field logs. It should be noted that these field analyzers, although calibrated daily, are only useful as indicators of the presence of significant contaminants. Because the instruments are sensitive to moisture and fluctuating ambient conditions, small concentrations listed on the field logs should be considered insignificant. In addition, the lifting of the cuttings by compressed air tends to strip volatiles from the soil samples. Therefore, the organic vapor concentrations listed for the soil samples represent an indication of the presence of gross contamination only, and in no way are intended to represent the actual levels of contaminants present in the formations.

When saturated zones were encountered during drilling, the drilling was stopped and a water sample collected from the formation. This sampling was accomplished in the following manner:

- o The compressed air used to circulate cuttings and water to the surface, was stopped. This allowed formation water to enter the center of the drill string, via the bit.

- o After allowing the water to rise in the drill pipe for a few minutes, the Radian geologist lowered a stainless steel Kemmerer sampler into the water. This sampler is sent down in an open position and once in position is closed, on both ends, by a trip weight. In some formations the water contained significant amounts of sediment which interfered with the Kemmerer seals. In these cases a Teflon bailer was lowered into the water to obtain a sample.

- o Immediately upon obtaining a sample, two volatile organic analysis vials (VOA vials) were filled and sealed, without headspace.

- o A portion of the remaining sample was then analyzed for pH and conductivity using a Myron L pDS meter. Temperature was also measured using a standard mercury thermometer.

- o A 500 ml plastic bottle was then filled for anion/cation analysis.

- o The remainder of the water sample was then gravity filtered, using 4 micron filter paper, to remove suspended sediment and placed in a 250 ml plastic bottle, with nitric acid preservative, for metals analysis.

- o The Kemmerer samplers and Teflon bailers were rinsed with deionized water following each sampling.

- All samples were chilled to approximately 4°C and transported to Radian laboratories.

Water samples were analyzed for:

- Calcium (Ca)
- Chloride (Cl)
- Carbonate (CO_3)
- Iron (Fe)
- Bicarbonate (HCO_3)
- Magnesium (Mg)
- Sodium (Na)
- Sulfate (SO_4), and
- Volatile organics (EPA 601)

Results of these analyses are given in Appendix 5-E.

3.5.2.3 Post-Drilling Activities

Activities occurring after the drilling of each reconnaissance boring included bore-hole closure and site cleanup. Borings were closed by pumping a slurry of Portland I and II neat cement (no aggregate) into the center of the drill pipe before removal of the pipe from the boring. Then, as sections of drill pipe were removed, additional cement slurry was pumped into the remaining pipe. This method seals the drilled hole from the bottom of the hole upwards to the land surface.

Following emplacement of the grout, the drilling area was cleaned and graded to remove any spilled cuttings, cement, or refuse. For borings on private property the property owner, when available, was asked to verify that the site cleanup was acceptable.

3.5.2.4 Water Level Measurements

As part of the overall effort to define the local geology/hydrology, the reconnaissance borings served as the principal data collection method. It was also planned that static water levels would be measured in wells both on- and off-base. After reviewing the well data for potential off-base measuring points it was determined that domestic wells in the area could not be used. This was based primarily on a lack of knowledge of well construction and the inability to obtain valid static water levels in active domestic wells. Because water samples from wells completed in multiple zones are not comparable to single-zone wells, and active wells may yield erroneous static levels (even during the cycle-off period) it was concluded that collection of water levels off base would not be cost-effective and would probably yield erroneous data.

Water levels were synoptically measured in on-base monitoring wells. Water levels were grouped according to well depth with wells less than 120 ft deep considered 'shallow', and wells 120 ft or deeper considered 'deep'.

3.5.3 Results

3.5.3.1 General

A total of 29 reconnaissance borings were drilled in the vicinity of McClellan AFB (Figure 3.5-2 and Plate 5) from July 23 to September 6, 1984. All borings were drilled to a depth of approximately 200 ft except RB-7 which, due to circulation problems, was terminated at 165 below land surface. From these borings a total of 1,160 formation samples and 96 water samples were collected. These samples resulted in 92 grain-size distribution analyses, 283 field parameter analyses, 768 laboratory anion/cation analyses, and 95 volatile organic analyses.

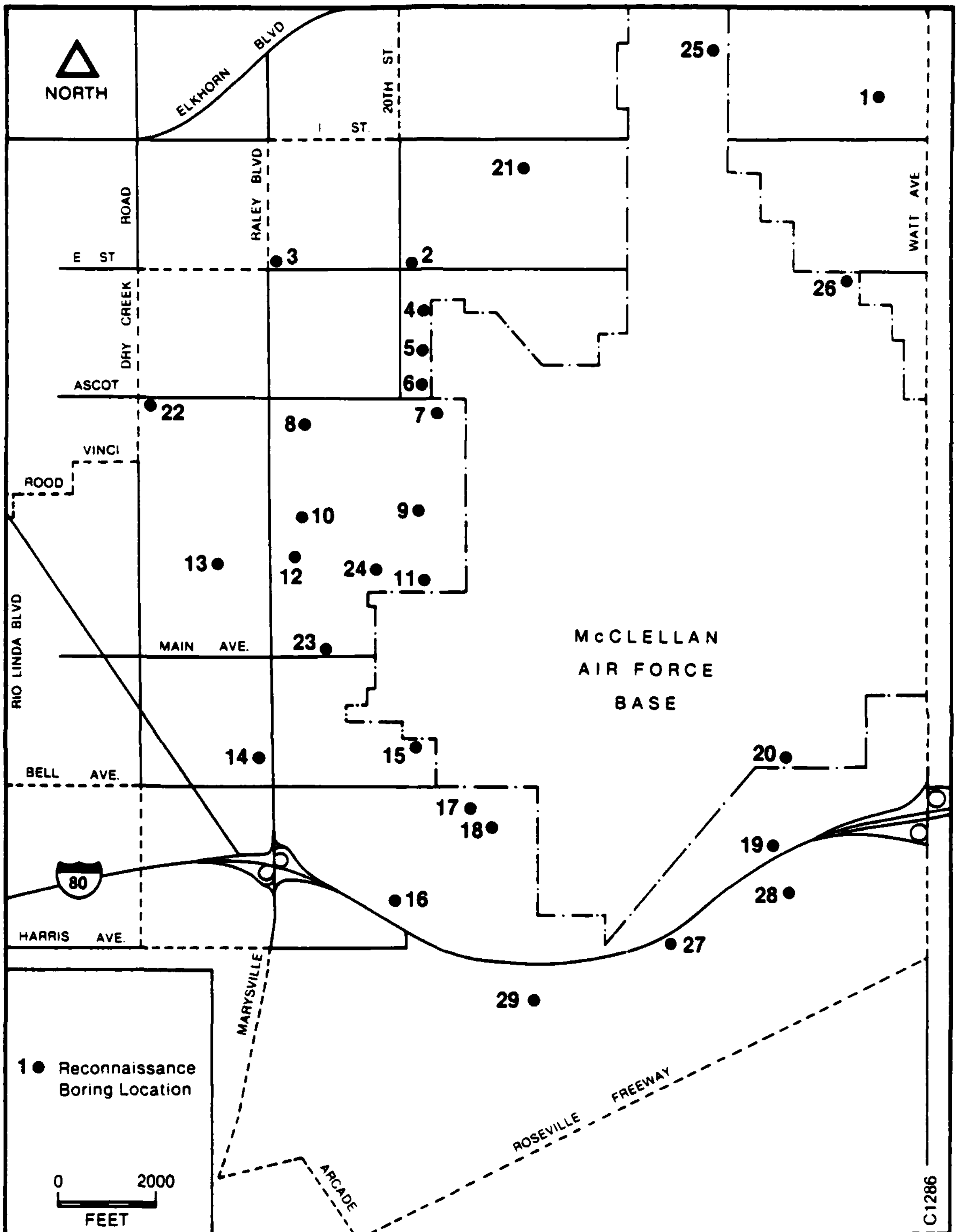

Figure 3.5-2. Location of Reconnaissance Borings

The results of the drilling activities and sample analyses are discussed in the following sections.

3.5.3.2 Geology

The area of the northern Sacramento valley occupied by McClellan Air Force Base is on the Victor Plain, a broad alluvial plain that extends from south of Sacramento to the northern boundary of Sacramento County. The Victor Plain is a depositional surface created by the meanderings of streams as they moved back and forth across the valley floor.

The Victor Formation consists of interbedded granitic sand, silt, and clay with occasional lenses of gravel. The lenses of gravel represent channel lag deposits left by the many braided streams that once flowed through the area. The sediments are extremely heterogeneous and discontinuous both laterally and vertically. Layers of hardpan occur in the uppermost part of the formation.

All of the reconnaissance borings penetrated the Victor Formation which is between 50 and 100 feet thick in the area of McClellan Air Force Base. The Victor Formation unconformably overlies the Fair Oaks and Laguna Formations. The average grain size appears to decrease westward on a regional scale, consistent with the decreasing ability of the streams to transport materials as they flow out across the plain. However, results of reconnaissance borings do not completely support regional trends (refer to discussion of hydrogeologic cross-sections).

The sands and silts of the Victor Formation are generally reddish to yellowish and contain abundant subrounded to subangular grains of quartz, feldspar (altered to clays), and micas (muscovite, biotite) as well as local concentrations of heavy minerals such as magnetite, pyroxene, and amphibole. The Victor Formation has an overall moderate permeability and yields little water except where wells penetrate the old channels.

In the area beneath McClellan Air Force Base, the top of the Victor Formation slopes to the west at about 5 feet per mile and the base of the formation slopes at about 11 feet per mile creating a gradual wedge forming to the west (California Department of Water Resources, 1974).

Underlying the Victor Formation is the Fair Oaks Formation which consists of poorly-graded, bedded silts, clays and sands with occasional lenses of gravel. The Fair Oaks Formation is reported as being generally between 0 and 225 feet thick in the area of McClellan AFB. The Fair Oaks Formation is characterized by white clay beds of altered volcanic tuff up to about 1 foot thick. The Fair Oaks Formation also yields little water except where the old stream channels are penetrated (California Department of Water Resources, 1974).

The Fair Oaks Formation laterally interfingers with the Laguna Formation. The Laguna Formation is a predominantly fine-grained, poorly-bedded, somewhat compacted continental deposit approximately 125 to 200 feet thick. This formation is an extremely heterogeneous assemblage of silt, sand, clay, and lenticular gravel beds. The most common deposits are light gray to yellow brown clayey silt to silty fine-grained sand. Clean, well sorted sand occurs chiefly in relatively thin zones that are laterally extensive. Gravel beds are scarce, poorly sorted and of low permeability. The sands are of granitic origin, with abundant weathered feldspars, biotite, and quartz grains. The sediments of the Laguna Formation are locally variable. Flakes of mica are locally abundant and serve as a distinguishing characteristic for the bulk of the formation. The Laguna and Fair Oaks Formations apparently are correlative in the upper sections beneath the Victor Formation in the McClellan area. The major difference between the Fair Oaks and the Laguna Formations is the presence of the white tuffaceous clay layers. The presence of the diagnostic white clay layers of the Fair Oaks Formation were

not observed during the drilling of the reconnaissance borings. The mica-rich sediments found in the lower zones of all the test borings supports the idea that the second formation encountered in the McClellan area may be the Laguna Formation and not the Fair Oaks Formation as previously assumed.

Discussion of Hydrogeologic Profiles (Plate 6)

Results of the reconnaissance borings showed greatly heterogeneous distribution of sediments, both vertically and horizontally. In order to interpret these results it was necessary to simplify the geologic logs into two basic divisions of the sediments encountered. One unit represents low permeability materials consisting of clay zones; the other unit represents sediments of higher permeability materials such as sand, silt, and gravel.

Using these simplified logs, eight hydrogeologic cross sections were developed. These cross sections are shown on Plate 6 and the locations of the cross sections are shown on Figure 3.5-3.

The cross sections are described briefly below and an interpretation is presented of the subsurface geologic conditions based on the cross sections. Although this interpretation is consistent with published sources, other interpretations are possible.

In general, the deposits are typical of alluvial plain deposits in that they are vertically and laterally discontinuous and variable, reflecting their origin as braided stream deposits. Because of this, correlation and definition of trends in the cross sections shown on Plate 6, is difficult. However, the lithologic variability is significant primarily in view of its effect on flow of ground water and pathways for contaminant migration. Specifically, these conditions suggest that the ability to predict vertical and lateral migration of contaminants on a site-specific scale will be highly dependent on detailed information on subsurface conditions in the area of interest.

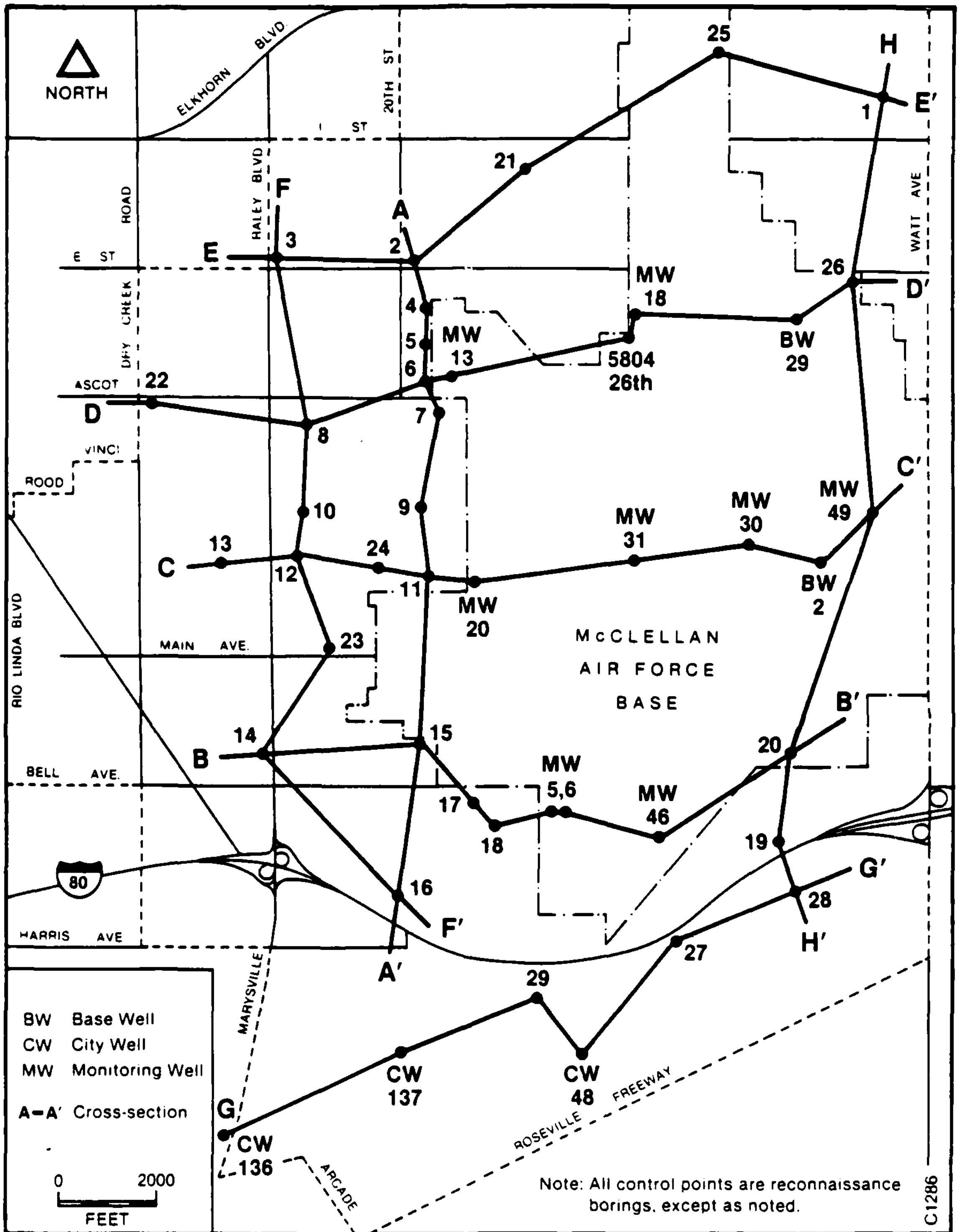

Figure 3.5-3. Location of Hydrogeologic Cross-Sections

Section G-G' (southern part of the base) shows a significant occurrence of clay that probably represents flood plain and flood basin deposits. These clays are much lower in hydraulic conductivity than the sands and gravels and act to retard the movement of the ground water. A thick package of sand with some gravel occurs between City Well 137 and RB-28; this sand represents stream channel deposits. The cross section of the stream channel correlates well with the position of the superjacent channel deposits previously mapped by others (California Department of Water Resources Bulletin 118-3, 1973). The old stream channels are reported to be areas of high hydraulic conductivity and relatively greater ground-water flow.

Section B-B' illustrates a section that contains a small amount of clay and a large volume of sand. These materials appear to represent braided stream channel deposits. An area of increased clay content is shown just southwest of the base in RB-15, RB-18, and Base Well 17. The cross section shows that the clay content of the sediments decreases from RB-15 to RB-14. This trend infers a higher hydraulic conductivity at RB-14 in the horizontal and vertical directions. The clays occurring in the subsurface at RB-15 may slow downward migration of the contaminants but, because of their limited horizontal extent, will not prevent migration of ground water except on a very localized basis.

Section C-C' shows some decrease in net clay content to the west and that sand, gravel and silt increase in the same direction. This section graphically illustrates the potential migration paths for ground water moving down the hydraulic gradient. Reconnaissance borings RB-24, RB-12, and RB-13, located west of the base, encountered contaminants downgradient from the base. The area between RB-11 and Monitor Well 30 is dominated by coarse sediments representing the superjacent stream channel deposits, which may have provided a pathway for contaminant migration.

Section D-D' shows a distinct decrease in clay content from east to west. A thick zone of clay occurs toward the eastern border of McClellan Air

Force Base. The clay begins about the location of the well at 5804 26th Street eastward to RB-26. The materials encountered in wells in this zone indicate flood basin and flood plain environment of deposition.

Section E-E' shows decreasing thickness and occurrence of clay to the west. Because of the increasing sand content of the sediments to the west, there is a potential for downward migration of contaminants.

Section H-H' extends north to south along the eastern edge of McClellan Air Force Base. A large deposit of clay occurs to the north and gradually thins to the south. The segment of the cross section that includes RB-20, RB-19, and RB-28 corresponds to the edge of one of the mapped superjacent deposits (California Department of Water Resources, 1973). RB-20 and RB-19 contain sand and scattered lenses of gravel consistent with a stream channel deposit.

Section A-A' extends along the western border of McClellan passing just west of Area D and through Area C. Clay content of the sediments decreases from north to south.

Section F-F' runs to the west of McClellan Air Force Base and Section A-A'. This section contains the greatest amount of sand of the sections, consistent with the decreasing clay content to the west.

During the drilling operations for the reconnaissance borings formation samples were collected, in saturated zones, for grain-size distribution analysis. These analyses provide results which will be used to select well screen slot sizes for monitoring wells to be installed. Table 3.5-1 is a summary of the grain-size distribution results. These analyses show that all water samples originated in either sand or sand/silt. Only one sample came from a clay/silt zone. The uniformity coefficients shown in Table 3.5-1 demonstrate that the sediments are extremely heterogeneous with respect to grain-size distribution. The extremely mixed nature of the grain-size dis-

TABLE 3.5-1. SUMMARY OF RECONNAISSANCE BORING SIEVE ANALYSES.

Boring Number (1-29)	Sampled Interval (Feet)	D40 Size (mm)	D90, Effective Size (mm)	Unif. Coef.(1) (D40/D90	Major Lithology (>50%) (2)
RB-1	127-135	0.1700	0.0320	5.3125	Sand
	160-165	0.0084	0.0008	10.1205	Silt/Clay
	180-190	0.0340	0.0010	34.0000	Silt/Sand
RB-2	90-100	0.0034	0.0022	1.5455	Silt
	135-140	0.0740	0.0010	74.0000	Sand/Silt
	156-160	0.1300	0.0040	32.5000	Sand/Silt
	175-180	0.0330	0.0025	13.2000	Silt
RB-3	95-130	0.2100	0.0028	75.0000	Sand
	155-165	0.0620	0.0012	51.6667	Silt/Sand
	170-180	0.3300	0.0120	27.5000	Sand
RB-4	95-100	0.3700	0.0600	6.1667	Sand
	135-141	0.8000	0.0062	129.0323	Sand
	155-160	0.3500	0.0056	62.5000	Sand
	190-220	0.2000	0.0660	3.0303	Sand
RB-5	90-100	0.1400	0.0010	140.0000	Silt
	115-120	0.0102	0.0013	8.1600	Silt
	135-140	0.4700	0.0032	146.8750	Sand
	175-180	0.0400	0.0025	16.0000	Silt
	195-200	0.4400	0.1500	2.9333	Sand
RB-6	90-100	0.0450	0.0021	21.4286	Silt
	135-140	0.9500	0.2700	3.5185	Sand
	170-180	0.2300	0.0110	20.9091	Sand
	190-200	0.2300	0.0470	4.8936	Sand
RB-7	135-140	0.5800	0.0600	9.6667	Sand
	155-160	0.7300	0.1070	6.8224	Sand
RB-8	100-120	0.0360	0.0016	22.5000	Silt
	135-140	0.0170	0.0025	6.8000	Silt
	155-165	0.1750	0.0023	77.4336	Sand
	170-220	0.8500	0.0050	170.0000	Sand
RB-9	100-103	0.1050	0.0017	61.7647	Sand
	120-127	0.1800	0.0028	64.2857	Sand/Silt
	140-160	0.5400	0.0500	10.8000	Sand
	165-200	0.3300	0.0031	106.4516	Sand

(Continued)

TABLE 3.5-1. (Continued)

Boring Number (1-29)	Sampled Interval (Feet)	D40 Size (mm)	D90, Effective Size (mm)	Unif. Coef.(1) (D40/D90	Major Lithology (>50%) (2)
RB-10	75-80	0.0250	0.0022	11.3636	Silt
	95-100	0.4500	0.0780	5.7692	Sand
	135-140	0.0370	0.0011	33.6364	Silt/Sand
	155-160	0.8200	0.2000	4.1000	Sand
RB-11	100-105	0.3700	0.0032	115.6250	Sand
	130-135	0.6600	0.0070	94.2857	Sand
	159-192	0.7200	0.0110	65.4545	Sand
RB-12	90-100	0.1200	0.0031	38.7097	Sand/Silt
	140-145	0.0270	0.0010	27.0000	Silt
	170-180	0.0430	0.0016	26.8750	Silt
	180-190	0.0720	0.0011	65.4545	Silt/Sand
RB-13	95-100	0.7400	0.0090	82.2222	Sand
	115-120	0.1200	0.0010	120.0000	Sand/Silt
	135-145	0.0130	0.0010	13.0000	Silt/Sand
	145-200	0.2500	0.0740	3.3784	Sand
RB-14	80-85	0.1050	0.0040	26.2500	Sand/Silt
	120-140	0.1900	0.0630	3.0159	Sand
	180-200	0.0320	0.0095	3.3684	Sand
RB-15	115-120	0.4400	0.0450	9.7778	Sand
	180-198	0.3300	0.0540	6.1111	Sand
	198-200	0.4400	0.1700	2.5882	Sand
RB-16	90-102	0.8100	0.0036	225.0000	Sand
	120-123	0.0230	0.0010	23.0000	Silt
	140-160	0.3000	0.0010	300.0000	Sand/Silt
	160-200	0.1700	0.0050	34.0000	Sand
RB-17	80-90	0.0250	0.0004	65.7895	Silt/Clay
	180-190	0.0830	0.0035	23.7143	Sand/Silt
RB-18	------				
RB-19	140-145	1.8000	0.0930	19.3548	Sand
	170-173	0.3300	0.0150	22.0000	Sand
	180-185	0.3400	0.0030	113.3333	Sand
	191-200	0.2800	0.0840	3.3333	Sand

(Continued)

TABLE 3.5-1. (Continued)

Boring Number (1-29)	Sampled Interval (Feet)	D40 Size (mm)	D90, Effective Size (mm)	Unif. Coef.(1) (D40/D90	Major Lithology (>50%) (2)
RB-20	140-145	0.1200	0.0022	54.5455	Sand/Silt
	150-155	0.3200	0.1600	2.0000	Sand
	170-180	0.0260	0.0012	21.6667	Silt
	180-190	0.0560	0.0011	50.9091	Silt/Sand
	195-200	0.3300	0.0058	56.8966	Sand
RB-21	130-140	0.2700	0.0037	72.9730	Sand
	170-180	0.2100	0.0700	3.0000	Sand
RB-22	95-105	0.1100	0.0029	37.9310	Sand/Silt
	140-145	0.4800	0.0110	43.6364	Sand
	175-180	0.4900	0.0220	22.2727	Sand
RB-23	80-90	0.0650	0.0028	23.2143	Silt/Sand
	155-160	0.0180	0.0002	120.0000	Silt
	175-180	0.6000	0.0021	285.7143	Sand
RB-24	85-90	0.2900	0.0069	42.0290	Sand
	95-110	0.4000	0.0025	160.0000	Sand
	120-130	0.4400	0.0420	10.4762	Sand
RB-25	150-160	0.1900	0.0230	8.2609	Sand
	187-190	0.1500	0.0022	68.1818	Sand
RB-26	140-150	0.0700	0.0026	26.9231	Silt/Sand
	200	0.2800	0.0500	5.6000	Sand
RB-27	150-160	0.0230	0.0020	11.5000	Silt
	180-190	0.0460	0.0013	35.3846	Silt/Sand
	190-195	0.1750	0.0190	9.2105	Sand
RB-28	120-125	0.0250	0.0072	3.4722	Silt
	180-185	0.4300	0.0550	7.8182	Sand
RB-29	135-145	0.0230	0.0010	23.0000	Silt/Clay
	150-160	0.0490	0.0022	22.2727	Silt/Sand
	180-185	0.1450	0.0042	34.5238	Sand

Note: (1) Unif. Coef: Denotes Uniformity Coefficient.
(2) Lithology based upon sieve analyses and M.I.T. Classification.

tribution is consistent with the meandering fluvial environment of deposition.

3.5.3.3 Ground Water

Occurrence of Ground Water

Ground water occurs in the spaces between the particles of a granular material within the zone of saturation. Coarse grained materials have larger pore spaces which are better connected than the pore spaces of fine-grained materials. The larger pore spaces allow for more flow of the ground water through the sediments such as sand or gravel. Materials that are very fine grained such as clay or silt have smaller pore spaces with less connection. This type of sediment will restrict the flow of ground water.

Ground water occurs in unconfined and confined zones in the McClellan area. Unconfined ground water is present where the water is in contact with the atmosphere via pore spaces in the sediments. The water within this zone generally forms the water table indicative of the top of the zone of saturation. When the ground water is separated from the atmosphere by an impermeable barrier it is called a confined aquifer. Confined ground water occurs at greater than atmospheric pressure, often called artesian pressure.

In the McClellan AFB area, ground water is unconfined in the relatively shallow flood plain and stream channel deposits. In some areas ground water is partially confined or confined beneath the clay and very fine silt beds. Ground water may also occupy zones above the main water table in what are known as perched water zones. Previous studies of the McClellan base area reported a number of these perched water zones (Engineering-Science, 1983; Luhdorff & Scalamini, 1983). The reconnaissance boring program encountered no perched water zones. The zones may have been absent because of the effects of seasonal climatic change. The perched zones are most likely to occur during periods of increased precipitation.

The aquifers encountered during the test drilling at McClellan are zones that contain saturated sediments and are permeable enough to yield water to the wells that penetrate them. Between these permeable, saturated zones exist beds of fine-grained materials such as fine silts and clays. These low permeability units restrict the flow of ground water between aquifers.

The most important hydrologic properties of the sediments beneath McClellan AFB are the rate at which water passes through the porous materials (transmissivity) and the ability of the sediments to store water (storage coefficient). These hydraulic properties control the yield and the drawdown characteristics of the aquifer. Coarse-grained sediments have higher transmissivity values and tend to yield large volumes of water to wells. Finer-grained sediments tend to yield only small volumes of water to wells due to low transmissivity.

Ground water in the vicinity of McClellan AFB was originally believed to occupy 3 or 4 separate zones within the first 200 feet of sediments. During the reconnaissance boring program, an air rotary, dual-tube drilling system was used to define the nature of the sediments and the occurrence of ground water zones in the area. During the drilling, hydrogeologists logged the sediments encountered and the levels at which aquifers were observed. The air drilling method allowed accurate indication of the zones in which water existed.

Ground water does not occur in widely correlatable zones beneath McClellan AFB as evidenced by the variability of the depths at which water was first encountered and variability in the depth of deeper saturated zones. The shallowest occurrence of ground water was at 75 to 80 feet below the land surface (BLS). The first occurrence of ground water ranged from 75 feet to as deep as 150 BLS with a mean depth for the first occurrence of water of 104 feet below land surface. Deeper saturated zones were encountered at widely varying depths and thicknesses. Analysis of an individual drilling log from

a well or boring may lead to a conclusion of separate aquifer zones. However, the hydrogeologic data from the reconnaissance borings, when correlated between borings, does not support continuity of individual aquifers throughout the study area. Although some trends are apparent, as discussed in the previous section, it appears that all saturated zones in the vicinity, are interconnected. The degree of these interconnections can only be assessed during comprehensive aquifer testing to be conducted in future stages.

Ground Water Flow

It was originally planned that ground-water levels would be measured in on-base monitoring wells and up to 30 off-base wells. Using data derived from the Data Review Task and the Well Inventory Task, Radian was unable to identify suitable off-base measuring points. A lack of knowledge of completion depths and multiple-zone completions, and active pumping were the principal reasons that off-base wells were not suitable. Water levels in on-base monitoring wells were measured during September 1984. The results are given in Table 3.5-2.

The water level results were divided into 'shallow' and 'deep' zones with all monitoring wells completed at a depth less than 120 ft below land surface being 'shallow'. All wells completed at depths of 120 ft BLS or greater were grouped as 'deep' wells. The results of these groupings are shown on Plate 7 (Shallow Ground-Water Elevations) and Plate 8 (Deep Ground Water Elevations). It is necessary to consider the shallow and deep zones separately because the elevation of water in the unconfined ground water will differ from the elevation of water in wells tapping only confined, or semiconfined aquifers. The depth of 120 feet was chosen as the separation point between 'shallow' and 'deep' zones because the uppermost occurrence of ground water was observed in most of the reconnaissance borings at depths between 90 and 120 feet. The second significant saturated zone generally occurred at depths greater than 120 feet.

TABLE 3.5-2. WATER LEVEL ELEVATIONS FOR ON-BASE MONITORING WELLS
(September, 1984)

Well Number	Land Elevation	Casing Stickup	Depth to Water	Water Level Elevation
MW 03	54.13	Did Not Sample		
MW 04	79.12	1.10	107.54	-27.32
MW 06	55.81	2.71	90.26	-31.74
MW 07	57.85	1.10	93.01	-34.06
MW 08	77.45	-0.20	101.24	-23.99
MW 09	78.05	-0.45	106.39	-28.79
MW 10	56.26	2.00	82.26	-24.00
MW 11	53.59	2.19	80.24	-24.46
MW 12	59.85	2.55	86.40	-24.00
MW 13	61.62	Well Destroyed		
MW 14	58.78	2.60	85.26	-23.88
MW 15	56.94	2.50	83.35	-23.91
MW 16D	80.70	-0.05	103.12	-22.47
MW 16S	80.70	-0.13	101.13	-20.56
MW 17D	73.30	-0.31	97.64	-24.65
MW 17S	73.30	-0.25	97.33	-24.28
MW 18D	69.20	1.77	96.27	-25.30
MW 18S	69.20	2.01	95.37	-24.32
MW 19D	57.9	1.79	84.01	-24.32
MW 19S	57.8	1.98	82.83	-23.05
MW 20D	60.10	1.91	87.69	-25.68
MW 20S	60.10	1.91	86.35	-24.34
MW 20D	57.50	1.72	81.45	-22.23
MW 21S	57.50	1.78	80.79	-21.51
MW 22D	60.00	1.74	89.90	-28.16
MW 22S	60.00	1.78	88.60	-26.82
MW 23D	58.80	1.90	94.51	-33.81
MW 23S	58.80	1.91	92.02	-31.31
MW 24D	58.20	1.73	95.49	-35.56

(Continued)

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TABLE 3.5-2. (Continued)

Well Number	Land Elevation	Casing Stickup	Depth to Water	Water Level Elevation
MW 24D	58.20	1.73	95.49	-35.56
MW 24S	58.20	1.71	91.56	-31.65
MW 25D	67.60	-0.82	95.44	-28.66
MW 25S	67.60	0.61	96.48	-28.27
MW 26D	70.50	0.12	103.50	-32.88
MW 26S	70.50	0.10	96.96	-26.36
MW 27D	71.80	1.50	103.02	-29.72
MW 27S	71.80	1.40	96.56	-23.36
MW 28D	72.60	1.47	99.61	-25.54
MW 28S	72.60	0.97 Dry		
MW 29D	68.50	1.50	95.76	-25.76
MW 29S	68.50	1.52	93.90	-23.88
MW 30S	73.00	-0.61	97.46	-25.07
MW 31	65.80	-0.15	91.73	-26.08
MW 33S	58.28	2.02	85.04	-24.74
MW 34S	58.17	2.10 Dry		
MW 35S	51.50	1.65	76.39	-23.24
MW 36S	56.14	0.89	80.71	-23.68
MW 38D	55.6	1.75	81.74	-24.39
MW 39S	67.96	- Dry		
MW 40S	67.76	1.11	95.77	-28.68
MW 41S	63.74	0.82	95.27	-30.71
MW 42S	56.58	1.06	90.39	-32.75
MW 43S	57.01	1.05	88.42	-30.36
MW 44S	53.79	0.83	78.48	-23.86
MW 45S	60.64	1.34	87.39	-25.41
MW 46S	65.67	0.92	96.11	-29.52
MW 47S	55.29	2.53	85.85	-28.03
MW 48S	54.23	2.37 Dry		

As can be seen on Plates 7 and 8, ground water, which flows perpendicular to contour lines toward lower elevations, flows generally toward the southwest. This is in agreement with previous investigations. However, in the vicinity of Area D, ground water appears to deviate from the southwesterly flow and move in a westerly and northwesterly direction. This is confirmed by the location of impacted wells (Plate 4) and reconnaissance boring samples as discussed in following sections.

As a measure of the potential for vertical migration of contaminants between zones, a head-difference map may be generated. By determining the difference in elevation between ground water in a confined aquifer (potentiometric surface) and the elevation of ground water in an unconfined aquifer, a difference in elevation, or head-difference, is derived. This is most easily accomplished using a computer with appropriate plotting software. Plate 9 is a computer-generated, head-difference map for the vicinity of McClellan AFB. The elevation of ground water in zones deeper than 120 ft BLS (Plate 8) was subtracted from the elevations of ground water in zones shallower than 120 ft BLS (Plate 7). Where the resultant difference is a positive number, there is the potential for water in shallower zones to move downward into deeper zones. Where the resultant difference is a negative number, there is a potential for water in deeper zones to move upward into shallower zones.

On Plate 9 it can be seen that the zero contour line passes along the western boundary of the base with positive head difference contours located to the east, within the base, and negative contours to the west mainly beyond the base boundary. This indicates that 'shallow' ground water under most of McClellan AFB has the potential to pass out of the unconfined zone and transport contaminants into deeper zones. To the west of the base, where head difference numbers are negative, there should be a potential for deep confined ground water to move upward into shallower zones, carrying contaminants with it. The head difference is probably caused by pumping of base supply wells, causing drawdown in the 'deeper' zones.

There are important factors which must be noted regarding Plate 9. First, the water level measurements that generated the Plate were taken late in the 'dry' season. During the winter months when rains are more plentiful it is likely that the 'shallow' ground-water table is at a higher elevation due to recharge. In such conditions, there may, in fact, be a negative head difference in those areas of the base for which a positive head difference existed during the dry season, creating the potential for downward migration of contaminants.

The second factor that must be considered is that Plate 9 was generated from only one round of water level measurements on base. Because no off-base data were used to generate the water level maps (and therefore the head-difference map) the computer extrapolated on-base data into the off-base area. It is possible that this extrapolation is incorrect. In order to develop a most accurate representation of the ground-water system, future water level data for both on-base and off-base measuring points and repetition of the data collection for different seasons, will be necessary.

<u>Ground Water Quality</u>

Field Analyses

As previously described, water samples were collected from each saturated zone encountered during reconnaissance boring drilling. These water samples were analyzed in the field for pH, conductivity, and temperature. The results of field analyses are given in Table 3.5-3 and discussed briefly below.

Temperature

Temperature readings were taken as rapidly as possible after samples were extracted from the borings. These temperature results demonstrated no correlation which could be used to differentiate distinct aquifer zones.

Temperature

Temperature readings were taken as rapidly as possible after samples were extracted from the borings. These temperature results demonstrated no correlation which could be used to differentiate distinct aquifer zones. In some areas, the first water encountered tended to have a slightly higher temperature than deeper samples. While this is an expected result due to recharge of water from the surface, the trend was not observed throughout the study area. The lack of distinct and consistent temperature changes between zones tends to support the conclusion that the saturated zones are not distinct, separated aquifers.

A possible source for notably different water temperatures would be recharge from surface water to ground water. It is believed that both Magpie Creek and Dry Creek recharge the ground water. This could be expected to result in a higher ground-water temperature during summer months if the recharge rate were high. However, this trend was not observed in borings near the creeks. Therefore, influences of the creeks could not be identified by temperature readings.

pH

Measurements of pH were taken in the field using a portable Myron conductivity/pH meter. The pH measurements varied between 4.3 and 9.8 (average 6.9) and generally did not correlate with depth. Area D reconnaissance borings did exhibit higher than average pH readings. Reconnaissance Borings RB-4 and RB-6 both contained an average pH reading of 8.4 and RB-5 had an average pH reading of 7.7. The pH readings did not indicate any correlation with aquifer zones in the study area. This tends to support the conclusion that the saturated zones are not distinct, separate aquifers.

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TABLE 3.5-3. SUMMARY OF GROUND-WATER QUALITY FIELD PARAMETERS

Boring Number (1-29)	Sample Depth (Feet)	Temp. (Degrees C)	pH	Field Conductivity (micromhos/cm)
RB-1	120	23	7.5	270
	140	23	7.4	160
	160	23	7.5	230
	180	21	7.4	170
	200	21	7.8	180
RB-2	100	23	6	230
	140	19	7.5	200
	160	18	7.8	210
	180	18	7.8	190
RB-3	100	22	4.3	200
	160	18	4.7	200
	180	20	5.6	190
RB-4	110	23	9.5	300
	140	19	9	210
	160	18	7.8	200
	200	18	7.5	210
RB-5	100	21	6.9	910
	120	19	7.5	2100
	140	18	7.5	400
	180	18	7.8	210
	200	18	8.9	300
RB-6	100	24	6.9	210
	140	18	7.9	300
	180	19	9	200
	200	18	9.8	210
RB-7	100	20	6.8	200
	140	18	7	210
	160	19	8.5	200
RB-8	100	25	6.5	200
	135	18	8	200
	160	18	7.2	210
	200	17	7.6	215

(Continued)

TABLE 3.5-3. (Continued)

Boring Number (1-29)	Sample Depth (Feet)	Temp. (Degrees C)	pH	Field Conductivity (micromhos/cm)
RB-9	100	23	8.2	300
	120	21	6.2	260
	160	21	6.4	240
	180	20	6.8	235
RB-10	80	20	6.9	210
	100	19	7	500
	140	18	7.1	490
	160	18	7.2	200
RB-11	100	20	6.4	215
	140	20	6.8	420
	160	19	6.7	425
RB-12	89	16	6.8	520
	140	18	6.8	265
	180	19	7.3	310
RB-13	100	22	5	260
	120	20	5.1	220
	140	20	5.4	260
	200	22	4.9	240
RB-14	85	22	5.7	250
	130	20	6	220
	200	22	5.8	240
RB-15	120	22	5.5	230
	160	18	6.2	215
	200	18	5.7	210
RB-16	100	21	5.2	220
	120	19	5.4	210
	160	18	5.6	200
	180	19	6.2	180
RB-17	120	18	6.2	240
	140	16	6.4	230
	190	18	6.4	250
RB-18	140	-	6.4	240

(Continued)

TABLE 3.5-3. (Continued)

Boring Number (1-29)	Sample Depth (Feet)	Temp. (Degrees C)	pH	Field Conductivity (micromhos/cm)
RB-19	120	21	4.5	485
	140	23	6.4	210
	180	27	7.2	210
	200	27.5	7.1	200
RB-20	140	23	7.4	185
	160	23	7.4	320
	180	23	7.6	300
	200	25	7.4	190
RB-21	140	21	4.5	200
	180	20	4.5	200
RB-22	100	22	5.4	260
	145	22	5.4	240
	180	18	6.2	200
RB-23	85	18	5.8	260
	160	19	6.2	260
	180	16	6	220
RB-24	90	23	6.5	210
	110	18	7.1	210
	130	19	7.5	250
RB-25	140	19	7.8	210
	160	21.5	8.2	750
	190	21	8.3	330
RB-26	120	22	7.3	170
	140	23	7.4	150
	200	21	7.5	200
RB-27	160	16	6.2	280
	190	15	6.8	240
RB-28	120	22	7	250
	160	24	7.2	200
	180	-	7	220
RB-29	145	20	6	300
	160	20	6.2	280

Conductivity

Conductivity measurements of water samples were made in the field using a portable Myron conductivity/pH meter. Generally, conductivity measurements did not correlate with depth, remaining essentially unchanged. Several higher than average conductivity readings were observed in areas of organic contamination such as in Area D. For example, Boring RB-5 conductivity readings at 100 feet and a 120 feet were 910 and 2100 umhos/cm respectively. Although higher conductivity does apparently correlate to areas of contamination, no natural correlations were observed that would allow definition of distinct aquifer zones on the basis of conductivity differences.

Laboratory Analyses

Water samples collected from the reconnaissance borings were analyzed in the laboratory for both inorganic and organic parameters. The inorganic analyses were conducted to determine natural water characteristics which may be useful in differentiating between distinct aquifers. Organic analyses were conducted to serve as an indicator of the presence of contaminants. Both the inorganic and organic analysis results are discussed below.

Inorganic Analysis

Water samples were analyzed for the following inorganic parameters:

- Calcium (Ca),
- Carbonate (CO_3),
- Chloride (Cl),
- Iron (Fe),
- Bicarbonate (HCO_3),
- Magnesium (Mg),
- Sodium (Na), and
- Sulfate (SO_4).

The analytical results are tabulated on Table 3.5-4 with the raw analytical data provided in Appendix 5-E. Data averages and ranges are provided on Table 3.5-5.

In general, the inorganic analytical results indicate that the ground water in the study area is generally of low mineralization. These results agree with the results of previous studies for the Sacramento County area. Most samples contained nearly equal concentrations of the cations sodium, magnesium, and calcium. The principal anion was bicarbonate. To assess the inorganic analysis results in more detail, the results for anions and cations were plotted onto a graph known as a Piper Diagram. This diagram (Figure 3.5-4) permits graphical representation of water characteristics as percentages of certain anions and cations (Piper, 1944).

To plot the inorganic results for a sample, the relative percentages of cations (Na, Mg, Ca) are placed on the trilinear plot, on the left, as a single point. Usually potassium (K) is summed with sodium but, since potassium is usually a very minor cation in ground water, it was not analyzed.

The relative percentages of anions (CO_3 + HCO_3, SO_4, Cl) are plotted as a point on the right-hand trilinear plot. The two points are then projected to a single point on the diamond plot in the center. This single point represents the chemical characteristics of the ground water, with respect to percentages of anions and cations.

On Figure 3.5-4, individual points are not shown in the two trilinear plots and only those points falling outside of the shaded area which represents 84% of all samples collected are shown on the diamond plot. This diagram indicates that most of the samples collected contain essentially the

TABLE 3.5-4. ANALYSIS RESULTS FROM RADIAN RECONNAISSANCE BORINGS WATER SAMPLES (INORGANIC)

BORING	SAMPLE	DEPTH	CA	CL	CO_3	FE	HCO_3	MG	NA	SO_4
RB-1	1	120	35	16	<1	5.9	76	21	30	114
RB-1	2	140	26	23	<1	44	79	23	21	3.5
RB-1	3	160	34	18	<1	74	78	35	23	33
RB-1	4	180	15	14	<1	6.1	93	12	17	1
RB-1	5	200	14	12	<1	11	87	12	14	1
RB-2	1	100	18	20	<1	1.2	96	11	22	7
RB-2	2	140	21	21	<1	6.7	96	13	22	6
RB-2	3	160	20	18	<1	2.7	85	9.6	25	6
RB-2	4	180	15	18	<1	0.9	84	9.5	22	6
RB-3	1	100	16	18	<1	0.01	95	12	26	15
RB-3	2	160	14	13	<1	2.3	104	10	19	1.3
RB-3	3	180	26	13	<1	73	84	26	24	1.6
RB-4	1	110	27	29	<1	2	143	21	28	9
RB-4	2	140	18	21	<1	0.13	92	13	26	7.9
RB-4	3	160	20	21	<1	5.6	95	14	23	7.7
RB-4	4	200	24	24	34	4	89	15	26	11
RB-5	1	100	110	57	<1	0.94	240	78	43	4.1
RB-5	2	120	330	140	<1	2.5	1045	190	61	290
RB-5	3	140	36	35	<1	5.2	191	30	26	6.7
RB-5	4	180	22	18	<1	1.7	92	12	20	7.5
RB-5	5	200	25	19	29	3.7	110	15	22	18
RB-6	1	100	49	69	<1	1.2	240	36	31	87
RB-6	2	140	24	29	<1	2.6	140	18	24	10
RB-6	3	180	26	21	55	0.36	86	12	20	7.7
RB-6	4	210	30	24	50	0.88	84	12	21	8.4

(Continued)

TABLE 3.5-4. (Continued)

BORING	SAMPLE	DEPTH	CA	CL	CO_3	FE	HCO_3	MG	NA	SO_4
RB-7	1	100	21	14	<1	8.9	78	13	24	6
RB-7	2	140	18	18	<1	1.8	99	11	21	5
RB-7	3	160	18	11	<1	3.1	128	11	18	2
RB-8	1	100	13	14	<1	4.4	69	9.5	17	4
RB-8	2	135	15	22	<1	1.7	99	11	21	7
RB-8	3	160	14	18	<1	2.8	80	11	20	5
RB-8	4	200	15	18	<1	2	83	11	22	6
RB-9	1	100	32	21	54	0.51	88	11	26	20
RB-9	2	120	20	18	<1	4.2	99	14	21	11
RB-9	3	160	22	20	<1	3.7	98	17	21	7.5
RB-9	4	180	19	21	<1	2.3	93	13	24	7
RB-10	1	80	24	26	<1	4.7	120	19	26	10
RB-10	2	100	22	24	<1	2.2	110	18	25	10
RB-10	3	140	120	21	<1	47	77	110	25	6
RB-10	4	160	14	17	<1	1.7	75	10	20	5
RB-11	1	100	15	20	<1	1.1	90	11	21	7
RB-11	2	140	19	19	<1	1.3	104	14	19	6
RB-11	3	160	20	18	<1	7.5	101	17	19	5
RB-12	1	89	26	24	<1	11	76	20	27	8
RB-12	2	140	25	22	<1	13	97	22	25	7
RB-12	3	180	22	22	<1	1.3	122	16	25	7
RB-13	1	100	24	29	<1	2	133	17	25	7
RB-13	2	120	20	23	<1	6.1	98	14	22	8
RB-13	3	140	21	24	<1	5.6	105	15	23	9
RB-13	4	200	21	24	<1	26	91	12	29	9

(Continued)

TABLE 3.5-4. (Continued)

BORING	SAMPLE	DEPTH	CA	CL	CO_3	FE	HCO_3	MG	NA	SO_4
RB-14	1	85	20	22	<1	4.8	88	16	18	5
RB-14	2	130	18	21	<1	11	88	15	18	5
RB-14	3	200	21	21	<1	14	103	19	18	5
RB-15	1	120	42	17	<1	60	87	39	28	8.9
RB-15	2	160	20	8	<1	13	98	17	18	1.6
RB-15	3	200	21	16	<1	27	88	20	21	3.7
RB-16	1	100	51	14	<1	70	80	52	24	9.5
RB-16	2	120	18	14	<1	3.7	80	11	26	5
RB-16	3	160	130	13	<1	54	89	130	25	5
RB-16	4	180	21	15	<1	8.9	93	15	18	5
RB-17	1	120	8.1	16	<1	2.1	112	6.3	7.7	5
RB-17	2	140	8.6	16	<1	2.3	96	6.1	7.6	9.2
RB-17	3	190	8.3	20	<1	2.6	95	6.1	7.4	6.7
RB-18	1	140	19	17	<1	26	88	22	15	4.5
RB-19	1	120	21	23	<1	0.95	108	13	19	5
RB-19	2	140	21	17	<1	22	96	17	21	3
RB-19	3	180	17	12	<1	1.5	103	12	16	3
RB-19	4	200	17	10	<1	3.7	110	11	17	2
RB-20	1	140	14	11	<1	14	77	10	10	4.5
RB-20	2	160	21	9.9	<1	0.69	82	14	10	200
RB-20	3	180	16	9.5	<1	15	92	13	9.6	55
RB-20	4	200								
RB-21	1	140	14	14	<1	0.84	83	9.2	22	6
RB-21	2	180	25	14	<1	28	81	20	30	5

(Continued)

TABLE 3.5-4. (Continued)

BORING	SAMPLE	DEPTH	CA	CL	CO_3	FE	HCO_3	MG	NA	SO_4
RB-22	1	100	20	25	<1	2.3	107	17	24	7.5
RB-22	2	145	16	22	<1	6.1	86	13	21	5.1
RB-22	3	180	14	16	<1	3	77	11	19	2.7
RB-23	1	85	21	18	<1	30	83	21	22	10
RB-23	2	160	17	17	<1	1.3	88	13	19	4
RB-23	3	180	19	17	<1	4	96	16	20	5
RB-24	1	90	19	21	<1	7.9	100	13	24	7.1
RB-24	2	110	19	21	<1	8.4	98	16	22	7
RB-24	3	130	19	20	<1	0.18	<1 ??	15	22	8
RB-25	1	140	23	13	<1	28	89	22	18	12
RB-25	2	160	110	15	<1	81	78	61	26	350
RB-25	3	190	24	14	<1	4.1	90	18	20	76
RB-26	1	120	12	13	<1	14	67	9.7	10	3.7
RB-26	2	140	5.6	13	<1	1.9	67	4.1	8.5	3.9
RB-26	3	200	8.7	14	<1	0.35	86	6.4	10	6.3
RB-27	1	160	19	44	<1	2.1	112	15	17	7
RB-27	2	190	16	14	<1	1.6	99	13	16	2
RB-28	1	120	22	18	<1	1.2	116	14	18	4.8
RB-28	2	160	15	13	<1	2.3	109	10	16	3.2
RB-28	3	180	19	13	<1	5.7	112	14	18	3.4
RB-29	1	140	22	20	<1	1.2	100	17	18	6.2
RB-29	2	160	19	20	<1	1.3	122	14	17	5.1

TABLE 3.5-5. SUMMARY OF INORGANIC ANALYSIS FOR WATER SAMPLES

Analyte	Maximum	Minimum	Average	Standard Deviation	Sample With Highest Concen.	Sample With Lowest Concen.
Ca	330	8.1	26.7	36.5	RB5-2	RB17-1
Cl	140	8	20	15	RB5-2	RB15-2
CO_3	55	< 1	44	12	RB6-3	*
Fe	70	0.01	10.7	17.7	RB16-1	RB3-1
HCO_3	1045	< 1	108.7	101.4	RB5-2	RB24-3
Mg	190	6.1	20.6	25.4	RB5-2	RB17-2 RB17-3
Na	61	7.4	21.2	7.0	RB5-2	RB17-3
SO_4	290	1	18.5	51.5	RB5-2	RB1-4 RB1-5

*90 samples contained < 1 Mg/L CO_3

5 samples contained measurable amounts of CO_3 and were used for calculations

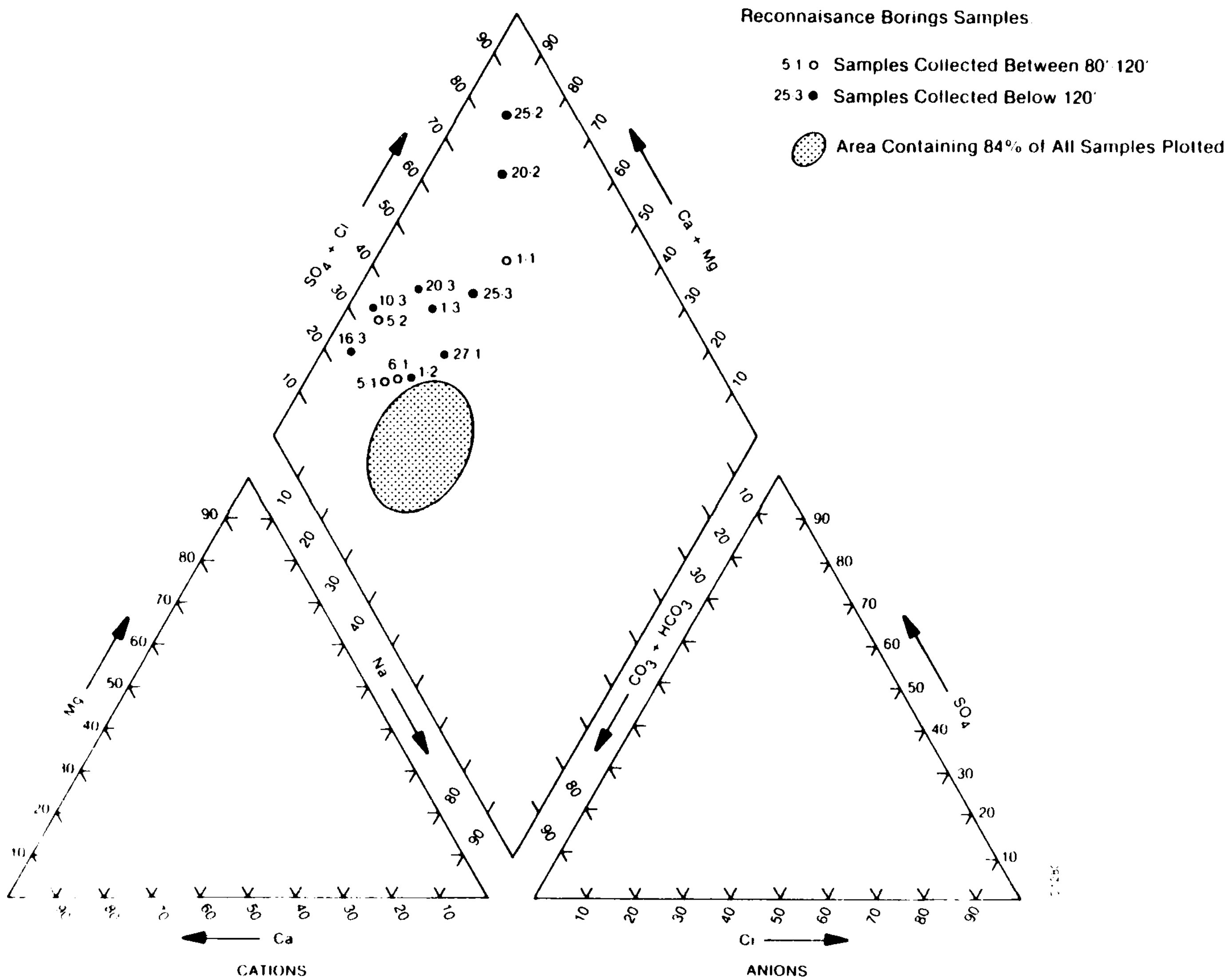

Figure 3.5-4. Piper Diagram of Anion/Cation Analyses for Water Samples from Reconnaissance Borings

same anion/cation relationships. This, in combination with the lack of correlatable differences in pH, temperature, and conductivity, tends to support the conclusion that the saturated zones in the area are not distinct, separate aquifers.

Water samples from the 'shallow' zones (80'-120' BLS) were very consistent in anion/cation ratios. Only four samples, RB-1-1, RB-5-1, RB-5-2, and RB-6-1, fell outside of the shaded area of the graph. All four of these samples were from areas of organic contamination where natural ion concentrations have apparently been altered.

Water samples from 'deeper' zones (below 120' BLS) showed slightly more varied results. Most samples still plotted within the shaded area but nine samples fell outside of the area. These nine samples do not correlate to contaminated areas, depths, or geographic area, although 4 of the 9 samples were collected northeast of the base.

Organic Analysis

Water samples collected from the reconnaissance borings were also analyzed for certain organic compounds by EPA Method 601. These analyses were conducted as a 'screening' for the presence of organic compounds in the ground water.

The EPA 601 Method is a gas chromatography analysis for purgeable halocarbon compounds. The organic compounds analyzed by EPA 601 are given in Table 3.5-6 along with the method detection limits. Results of the EPA 601 analyses conducted on the ground water samples from the reconnaissance borings are given in Table 3.5-7. Laboratory results are given in Appendix 5-E.

The California Department of Health Services has assigned 'Action Levels' to certain EPA 601 compounds in ground water at McClellan AFB. These Action Levels are given in Table 3.5-8.

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TABLE 3.5-6. EPA METHOD 601 COMPOUNDS (PURGEABLE HALOCARBONS) AND METHOD DETECTION LIMITS (ug/L)

Chloromethane	0.08	Trichloroethene	0.12
Bromomethane	1.18	Dibromochloromethane	0.09
Vinyl Chloride	0.18	1,1,2-Trichloroethane	0.02
Chloroethane	0.52	cis-1,2-Dichloropropene	0.20
Methylene Choride	0.25	2-Chloroethylvinyl Ether	0.13
Trichlorofluoromethane	ND	Bromoform	0.20
1,1-Dichloroethene	0.13	1,1,2,2-Tetrachloroethane	0.03
1,1-Dichloroethane	0.07	Tetrachloroethylene	0.03
trans-1,2-Dichloroethene	0.10	Chlorobenzene	0.25
Chloroform	0.05	1,3-Dichlorobenzene	0.32
1,2-Dichloroethane	0.03	1,2-Dichlorobenzene	0.15
1,1,1-Trichloroethane	0.03	1,4-Dichlorobenzene	0.24
Carbon Tetrachloride	0.12		
Bromodichloromethane	0.10		

ND - Not Determined

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TABLE 3.5-7. ANALYSIS RESULTS FROM RADIAN RECONNAISSANCE BORINGS WATER SAMPLES (ORGANIC)[1]

Boring	Sample	Depth	Vinyl Chloride	Meth. Chloride	Freon[2] 11	1,1DCE[3]	1,1DCA[4]	trans-[5] 1,2DCE	Chloroform	1,2DCA[6]	1,1,1[7] TCA	Bromo-[8] DCM	TCE[9]	DBCM[10]	1,1,2,2[11] TCA	Chlorobenzene	1,3DCB[12]	1,2DCB[13]	Total EPA 601 Compounds
RB-1	1	120	ND	80.3	0.8	2	ND	ND	ND	ND	ND	ND	0.5	ND	2.5	ND	ND	ND	86.1
RB-1	2	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-1	3	160	ND	1.7	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.6
RB-1	4	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-1	5	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-2	1	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-2	2	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-2	3	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-2	4	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-3	1	100	ND	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1
RB-3	2	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-3	3	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-4	1	110	ND	ND	ND	0.1	0.6	ND	ND	ND	0.6	ND	ND	0.1	ND	ND	ND	ND	1.4
RB-4	2	140	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
RB-4	3	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-4	4	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-5	1	100	747	ND	ND	517	586	ND	ND	15.9	16.3	ND	2.3	23.3	1.8	3.9	ND	6.6	1920.1
BR-5	2	120	686	ND	ND	268	330	ND	ND	48.2	25.4	ND	1.7	ND	1.7	ND	ND	20	1381
RB-5	3	140	ND	ND	ND	77.6	57	ND	ND	4.1	ND	ND	2.2	ND	ND	ND	ND	ND	140.9
RB-5	4	180	ND	ND	ND	ND	ND	ND	ND	ND	0.9	ND	ND	ND	ND	ND	ND	ND	0.9
RB-5	5	200	ND	ND	ND	ND	ND	ND	ND	0.5	1.6	ND	ND	ND	ND	ND	ND	ND	[illegible]
RB-6	1	100	ND	ND	ND	19.7	5.1	2.3	ND	110	ND	ND	242	ND	ND	ND	41.6	ND	420.7
RB-6	2	140	ND	ND	ND	1.3	0.1	ND	ND	5.8	ND	ND	7.7	ND	ND	ND	ND	ND	14.9
RB-6	3	180	ND	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND	0.2
RB-6	4	210	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-7	1	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-7	2	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-7	3	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-8	1	100				SAMPLE		BROKEN		DURING			HANDLING						
RB-8	2	135	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-8	3	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-8	4	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-9	1	100	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
RB-9	2	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-9	3	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-9	4	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-10	1	80	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-10	2	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-10	3	140	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4
RB-10	4	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0

(Continued)

TABLE 3.5-7. (Continued)

Boring	Sample	Depth	Vinyl Chloride	Meth. Chloride	Freon[2] 11	1,1DCE[3]	1,1DCA[4]	trans-[5] 1,2DCE	Chloroform	1,2DCA[6]	1,1,1[7] TCA	Bromo-[8] DCM	TCE[9]	DBCM[10]	1,1,2,2[11] TCA	Chlorobenzene	1,3DCB[12]	1,2DCB[13]	Total EPA 601 Compounds
RB-11	1	100	ND	ND	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2
RB-11	2	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-11	3	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-12	1	89	ND	ND	ND	ND	1.2	1.3	0.1	0.1	ND	ND	0.7	ND	ND	ND	ND	ND	3.4
RB-12	2	140	ND	ND	ND	0.1	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
RB-12	3	180	ND	ND	ND	ND	0.3	0.2	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	0.7
RB-13	1	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-13	2	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-13	3	140	ND	ND	ND	ND	ND	ND	ND	ND	1.3	ND	ND	ND	ND	ND	ND	ND	1.3
RB-13	4	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-14	1	85	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-14	2	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-14	3	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-15	1	120	ND	1.8	0.2	ND	ND	ND	ND	ND	0.5	ND	ND	ND	ND	ND	ND	ND	2.5
RB-15	2	160	ND	0.5	ND	ND	ND	ND	ND	ND	0.5	ND	ND	ND	ND	ND	ND	ND	1
RB-15	3	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-16	1	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-16	2	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-16	3	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-16	4	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-17	1	120	ND	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7
RB-17	2	140	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1
RB-17	3	190	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-18	1	140	ND	ND	ND	ND	ND	1.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.6
RB-19	1	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-19	2	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-19	3	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-19	4	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-20	1	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-20	2	160	ND	1.5	2.2	ND	ND	ND	ND	ND	2.4	ND	ND	ND	ND	ND	ND	ND	6.1
RB-20	3	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-20	4	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-21	1	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-21	2	180	ND	ND	ND	ND	ND	ND	ND	ND	0.7	ND	ND	ND	ND	ND	ND	ND	0.7
RB-22	1	100	ND	ND	ND	0.8	ND	ND	ND	ND	0.3	ND	0.3	ND	ND	ND	ND	ND	1.4
RB-22	2	145	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-22	3	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0

(Continued)

TABLE 3.5-7. (Continued)

Boring	Sample	Depth	Vinyl Chloride	Meth. Chloride	Freon[2] 11	1,1DCE[3]	1,1DCA[4]	trans-[5] 1,2DCE	Chloroform	1,2DCA[6]	1,1,1[7] TCA	Bromo-[8] DCM	TCE[9]	DBCM[10]	1,1,2,2[11] TCA	Chlorobenzene	1,3DCB[12]	1,2DCB[13]	Total EPA 601 Compounds
RB-23	1	85	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-23	2	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-23	3	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-24	1	90	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-24	2	110	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4
RB-24	3	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-25	1	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-25	2	160	ND	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3
RB-25	3	190	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-26	1	120	ND	ND	ND	ND	ND	ND	ND	ND	0.9	ND	ND	ND	ND	ND	ND	ND	0.9
RB-26	2	140	ND	ND	2.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.2
RB-26	3	200	ND	ND	ND	ND	ND	ND	ND	ND	0.9	ND	ND	ND	ND	0.4	ND	ND	1.3
RB-27	1	160	ND	ND	1.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.9
RB-27	2	190	ND	ND	0.6	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND	ND	0.8
RB-28	1	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-28	2	160	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-28	3	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-29	1	145	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
RB-29	2	160	ND	1.1	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.9

Footnotes to Table 3.5-7

[1] Only EPA 601 compounds detected are listed.
[2] Freon 11 = Trichlorofluoromethane
[3] 1,1 DCE = 1,1 Dichloroethene
[4] 1,1 DCA = 1,1 Dichloroethane
[5] trans-1,2 DCE = trans-1,2 Dichloroethene
[6] 1,2 = 1,2 Dichloroethane
[7] 1,1,1 TCA = 1,1,1 Trichloroethane
[8] Bromo DCM = Bromodichloromethane
[9] TCE = Trichloroethene
[10] DBCM = Dibromochloromethane
[11] 1,1,2,2 TCA = 1,1,2,2 Tetrachloroethane
[12] 1,3 PCB = 1,3 Dichlorobenzene
[13] 1,2 DCB = 1,2 Dichlorobenzene

TABLE 3.5-8. ACTION LEVELS FOR ORGANIC COMPOUNDS IDENTIFIED IN GROUND WATER, McCLELLAN AFB, CALIFORNIA

Compound	Action Level or MCL[1] (ug/L)
Chloroform	100
1,1-Dichloroethane	ND[2]
1,2-Dichloroethane	1
1,1-Dichloroethene	detection limit (0.1)
trans-1,2-Dichloroethene	ND
Methylene Chloride	40
1,1,1-Trichloroethane	300
Trichloroethene	5
Vinyl Chloride	2
Dichlorobenzene	130[3]

Source: California Department of Health Services, 1983.

[1]Maximum Contaminant Level

[2]No data available

[3]Action level for dichlorobenzene is either for a single isomer or for the sum of three isomers (1,2-; 1,3- and 1,4-).

An assessment of the organic analysis results shows that organic compounds were detected in 21 of the 29 reconnaissance borings. It must be noted, however, that for 6 of the 21 borings, the only compound detected was trichlorofluoromethane (Freon 11). This compound, an air conditioning fluid, is often seen as a spuriously detected compound, even in field blanks. Lab blanks run concurrent with samples showed no evidence of trichlorofluoromethane. The high vapor pressure of the compound creates the potential for a sample to acquire trichlorofluoromethane during transit or during storage. It is Radian's opinion that the existence of this Freon 11 as the only compound detected in 6 borings is a result of interferences after sampling and that these 6 borings should be considered free from contaminants.

Of the remaining 15 borings for which organic compounds were detected, only 6 borings exceeded California DHS Action Levels. These are given in Table 3.5-9.

The principal area of contamination, as expected, was near Area D. Reconnaissance borings RB-4, RB-5, and RB-6 all showed varying concentrations of organic compounds.

In RB-5, two samples were taken in what was probably the same 'shallow' ground-water zone. Both of these samples (100 and 120 ft BLS) displayed similar organic compound distribution. Vinyl chloride, 1,1 dichloroethene, and 1,1 dichloroethane were the principal contaminants with up to seven other compounds seen in lower concentrations.

Although trichloroethene (TCE) was believed to be one of the principal spent solvents disposed of in Area D, relatively low concentrations were observed in RB-5. The physical process of volatilization of the TCE during drilling was considered. The potential for volatilization of TCE during the dual tube air rotary drilling process is low. The air flow that occurs during the drilling circulates within the drill bit and drill stem.

TABLE 3.5-9. RECONNAISSANCE BORINGS EXCEEDING ACTION LEVELS

Boring	Compounds Exceeding Action Levels
RB-1	1,1 Dichloroethene, Methylene Chloride
RB-4	1,1 Dichloroethene,
RB-5	1,1 Dichloroethene, 1,2 Dichloroethane, Vinyl Chloride
RB-6	1,1 Dichloroethene, 1,2 Dichloroethane, Trichloroethene
RB-12	1,1 Dichloroethene
RB-22	1,1 Dichloroethene

The circulation process forces the air under pressure to return up through the center tube as shown in Figure 3.4-1. The contact between any formation fluids and the drilling air is of short duration. When air is forced into the bit area the directional pressures of circulation restrict formation contact to a radius just beyond the bit. The radius of the air penetration is determined by injection pressures and formation characteristics. During water sampling, the air injection is halted allowing a strong infusion of formation fluids to the well bore. The bulk of these fluids represent non-aerated water which should contain unaltered concentrations of volatiles. Recently, there has been speculation that TCE degrades to other compounds which may explain the lower TCE values. Parsons, et. al. (1984) showed that under anaerobic conditions tetrachloroethene degraded to trichloroethene, cis-1,2 dichloroethene, chloroethene, dichloro- methane, and trans-1,2 dicaahloroethene due, apparently, to biologic activity in organic mucks. But, the autoclaved muck samples in the Parsons experiment did not show any significant degradation of tetra- or tri-chloroethene. It is unknown if any anaerobic, biologically rich environment is present in Area D, sufficient to cause TCE degradation.

Degradation of TCE by non-biologic activities may be a possibility but degradation to vinyl chloride is unlikely, thereby leaving the origin of the vinyl chloride in question. In the raw laboratory data given in Appendix 5-F it can be seen that the chromatogram peak interpreted as vinyl chloride (Sample RB-5-1 and RB-5-2) does not fall directly on the vinyl chloride standard peak at a retention time of 4.07 minutes. It is possible that the peak seen for each sample may be due, in part, to the presence of chloroethane, as well as vinyl chloride.

Reconnaissance boring RB-5 is also useful in assessing the vertical migration of contaminants in the vicinity of Area D. The concentration of all contaminants seen in the 'shallow' zone (100-120 ft) decreased with depth. Sample RB-5-3 (140 ft) did show the presence of organic contaminants although in much lower concentrations than the 'shallow' zone. Only minor

quantities of contaminants were present in samples from 180 feet and 200 feet BLS.

Other areas of contaminant detection included the area northeast of the base (RB-1), and minor concentrations in borings drilled south, southwest, and west of the base. These are discussed below:

- o Reconnaissance Boring RB-1 (Northeast of Base). Relatively low levels of methylene chloride and 1,1 - dichloroethene were detected in an area believed not to be impacted. The source of this contaminant is unknown. Recently measured ground-water levels indicate that flow in the northeast area of the base is generally northeast to southwest. Therefore the evidence does not suggest that contaminants in RB-1 came from McClellan AFB.

- o Reconnaissance Boring RB-12 (West of Base near Magpie Creek). Relatively low levels of several compounds were detected, mostly in the 'shallow' zone (89 ft. BLS). These compounds may have originated at McClellan AFB, been transported by Magpie Creek and recharged to the ground water. It is also possible that the contaminants may have migrated into the ground water from Area C. However, this is considered unlikely because contaminants were not seen in borings RB-11 and RB-24.

- o Reconnaissance Boring RB-13 (West of the Base off Santa Ana Ave.). Only 1,1,1 Trichloroethane was detected in low concentrations, and only in the sample from 140 ft. BLS. The origin of this compound is unknown but is probably not a locally recharged contaminant (as from Magpie Creek) because it was not detected in 'shallow' zone samples.

- o Reconnaissance Boring RB-15 (Southwest of Base near Base Boundary). Minor levels of two organic compounds, plus Freon 11, were seen in the 'shallow' zone at a depth of 120 ft BLS, and also 160 ft BLS (no Freon 11). Because this boring is downgradient from many potential contaminant sources on-base, the actual source is unknown. There is no reason to suspect that the contaminants came from any source other than McClellan.

- o Reconnaissance Boring RB-17 (Southwest of Base near City Well 150). Minor concentrations of methylene chloride were detected at 120 feet and 140 feet BLS. RB-17 was essentially downgradient of Area B and other possible on-base sources. Although it is most probable that the contaminant originated on McClellan, it is also possible that degreasing liquids and other fluids being disposed of in a well on Winters St. (identified by Radian personnel during the Well Inventory) may be the source.

- o Reconnaissance Boring RB-18 (Southwest of Base near Boundary and Area B). Only one sample could be obtained from RB-18 and it showed trans-1,2 dichloroethene in minor concentrations. (See comments for RB-17, above).

- o Reconnaissance Boring RB-20 (Onbase South of Area A). Two compounds, plus Freon 11, were detected at 160 ft. BLS. While it is likely that these originated at Area A, it is not known why they were not detected in zones above or below 160 ft. RB-19, located farther south, did not contain any organic compounds.

- o Reconnaissance Boring RB-21 (Northwest of Base). Only a minor concentration of 1,1,1 trichloroethane was detected at 180 ft BLS. The source of this compound, and the reason it is seen

only in the deeper sample, is unknown. It is also not known why no significant ground water was encountered until 130 ft. BLS, much deeper than most other borings.

- Reconnaissance Boring RB-22 (West of Base near City Well 154). Three compounds were detected in low concentrations at 100 ft. BLS. All 3 compounds were the same as those seen near Area D, but it is unknown if Area D is the source. It is considered unlikely that contaminants have migrated that far in the 'shallow' ground water, especially since some domestic wells located between Area D and RB-22 have not been impacted, according to previous testing data. It is more probable that Little Rio Linda Creek may have been transporting contaminants and recharging to ground water, or that there is an unidentified local source of contaminants.

- Reconnaissance Boring RB-26 (on base in northeast area). Minor amounts of 1,1,1-trichloroethane were detected at 120 feet and 200 feet BLS. The source of these compounds is unknown but, based on ground-water flow direction it is believed they are not originating on-base.

- Reconnaissance Boring RB-27 (South of Base). No significant ground water was encountered until 150 ft. BLS. In the two samples collected (160 ft and 190 ft). Trichlorofluoromethane was detected. The only other compound detected was bromodichloromethane at 190 ft BLS. The source of this is unknown.

- Reconnaissance Boring RB-29 (South of Base). As with nearby RB-27, ground water was not encountered in shallow zones. The

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first significant ground water (135 ft BLS) was sampled at 145 feet BLS and showed no contaminants. The deeper sample (160 ft BLS) contained methylene chloride and Freon 11. The source of this is unknown.

In order to assess the impact of organic compounds on the ground water, all compounds detected by the EPA 601 Method analyses were summed and are shown in the right-hand column of Table 3.5-7. Because the 'shallow' ground water showed the most impact, the total concentration of 601 compounds for zones 120 ft BLS or shallower were used to generate Plate 10. This map, which includes total 601 compounds detected in on-base monitoring wells, shows isopleths which indicate the general level of organic contamination. Due to the widely varying values (0 to approximately 80,000 ug/L) it was necessary to contour, using the logarithmic values (base 10). Also, it should be noted that the most recent base monitoring well sampling data were not yet available. Therefore, values utilized for on-base monitoring wells are not synoptic with the reconnaissance boring data.

3.5.4 Conclusions

The reconnaissance boring program and associated activities developed a better understanding of near surface geology and hydrology in the vicinity of McClellan AFB. The following general conclusions were developed as a result of the Reconnaissance Boring task combined with the results of the Data Review task.

- Geologic units encountered within the first 200 feet below land surface were the Victor Formation and probably the Laguna Formation. Characteristic white tuffaceous beds of the Fair Oaks Formation were not encountered or identified during drilling.

- All subsurface geologic units (0-200 ft BLS) are extremely heterogeneous. Beds of sands, silts, and some gravels are separated by lenses of clays. None of these beds are correlatable over significant distances.

- General geologic trends indicate that the percentage of clays encountered in reconnaissance borings decreases north-to-south and east-to-west.

- Ground water occurs as an unconfined aquifer generally from 90-120 ft BLS. In some areas, however, the first significant ground water was encountered below 120 ft BLS.

- Deeper ground-water zones occur in discontinuous sequences of sand and silt lenses, probably as semiconfined zones which are not laterally extensive.

- Ground-water flow appears to be generally southwest but significant deviation from this direction probably occurs in areas of extensive pumping. One such deviation is the apparent flow of ground water to the west and northwest in the vicinity of Area D.

- Ground-water quality is generally good, with low mineralization, except in areas of contamination. Organic compounds were detected west of Area D, in the area northeast of the base, and in lesser concentrations in areas west, southwest, and south of the base.

- Contaminants found near Area D have been transported by ground water, but contaminants found farther west of the base may have been transported initially within Magpie and Dry Creeks.

- Contaminants found south of the base are of an unknown origin. It is most probable that they are from base sources. However, other potential sources, although minor, have been identified.

- Contaminants found northeast of the base are apparently upgradient of the base and a substantial distance from any McClellan waste area. The source of these contaminants is unknown. There is no reason to conclude, however, that these contaminants are a result of waste disposal activities on base.

3.6 Task 6 - Aquifer Test Planning

3.6.1. Objective

The objective of the Aquifer Test Planning task was to develop a methodology by which important aquifer parameters could be derived. These parameters--transmissivity, storativity, leakance, and anisotropy--can only be derived in field tests that 'stress' the aquifers by pumping or injecting water. There are, however, many types of aquifer tests which must be considered in planning an appropriate and cost-effective methodology.

3.6.2 Approach

The approach to Aquifer Test Planning included the following steps:

- Assessment of geologic/hydrologic information with respect to the ability to characterize aquifer parameters,
- Assessment of aquifer testing procedures and their application at McClellan, and
- Development of the Aquifer Test Plan to be implemented during Phase II, Stage 2-2.

The assessment of geologic/hydrologic information was conducted after the reconnaissance borings had been drilled and data from the borings reduced and analyzed. Particular emphasis was placed on assessing the distribution of saturated and confining zones. This information determined how many aquifer tests would be required to properly quantify aquifer parameters in the McClellan AFB area.

Aquifer testing procedures were reviewed with respect to meeting the objectives and scientific requirements for the McClellan investigation. Of

particular concern was the ability of aquifer testing to assess the interconnection of multiple aquifer zones and the effects of long-term pumping in areas where ground water may be extracted as a remedial action.

3.6.3 Results

Two types of aquifer tests were selected for determining aquifer parameters. The first is a comprehensive, long-term test utilizing pumping and observation wells. The second type of aquifer testing are short-term pumping or "slug" tests to be performed on monitoring wells as they are installed.

Because the area west of the base, particularly near Area D, is the probable location of remedial action pumping, it is imperative that this area be tested by a long-term aquifer test. The best location for this test would be the large, vacant lot which adjoins the western boundary of the base, to the southwest of Area D. This allows sufficient room to conduct the test, is close enough to Area D to represent that area, and is not in an area of contaminated water. The long term pump test in this area should not be considered definitive for the entire hydrogeologic system in the McClellan AFB area. The variability of sediments deposited in an ancient fluvial system such as exists at McClellan would best be defined by aquifer tests performed in different areas. The focus of the aquifer testing will be on the Area D locale since the remedial program is planned for the area.

Design of the long-term aquifer test was based on the results of reconnaissance boring information in the area west of the base which indicated that a relatively thin water table aquifer (unconfined aquifer) exists at an average depth of 90-100 feet below land surface (BLS). This zone probably does not yield significant volumes of water and would not adequately support an aquifer pumping test that induces significant drawdowns. The unconfined aquifer is separated from deeper zones by a sequence of silty-clays with small sand lenses. This sequence probably is not a good confining

bed but does provide partial hydraulic separation between zones. From 130-140 ft. BLS, sand lenses form a 'middle' aquifer. These lenses yield significant water volumes but probably do not form a laterally extensive aquifer.

Below the 'middle' aquifer, a sandy-clay separates the sand lenses from a more extensive micaceous sand which begins at approximately 160 ft. BLS. This 'deeper' aquifer zone probably has partial hydraulic connection with the above sand lenses.

Based on this hydrogeologic sequence, the aquifer test was designed to utilize two pumping wells and 9 observation wells. The following procedure will be utilized:

- o One well will be drilled into the 'middle' aquifer and completed as a pumping well. The actual zone of completion (screen length and depth) will be determined during drilling activities.
- o A second well will be drilled into the 'deeper' aquifer and completed as a pumping well. The placement and length of the screened interval will be determined during drilling activities.
- o Three clusters of 3 observation wells will be installed, each observation well will be singly completed but clustered in close proximity.
- o Following completion of all wells, water levels will be monitored for 12 hours prior to initiation of pumping.
- o Pumping will then be initiated in the 'middle' aquifer. Water will be extracted at a constant rate for 48-72 hours. It is anticipated that the pumping rate will be 50-100 gallons per minute.

- During pumping, water levels will be monitored in all wells using a multi-channel, continuous reading instrument. In addition, pumping discharge will be measured for discharge rate, temperature, pH, and conductivity.

- At the conclusion of pumping, the pump will be shut down and water level recovery in each well will be monitored for at least 12 hours.

- Following a period for aquifer stabilization, the pump will be placed in the 'deeper' aquifer and the test repeated.

- During both tests, all water discharged from the pumping wells will be collected in tank trucks, tested for contaminants, and discharged to the appropriate treatment system. It is assumed that this will be either the sanitary or industrial treatment facility.

Figure 3.6-1 shows the construction details for the pumping wells, Figure 3.6-2 shows the construction details for the observation well clusters, and Figure 3.6-3 is a block diagram showing the relative positioning of the pumping wells and piezometer cluster screens.

At the conclusion of the long-term aquifer test, the data collected will be evaluated in order to determine aquifer properties. Data collected during the test will include:

- Time vs. drawdown data for the pumping well,

- Time vs. drawdown data for observation wells in the pumping zone,

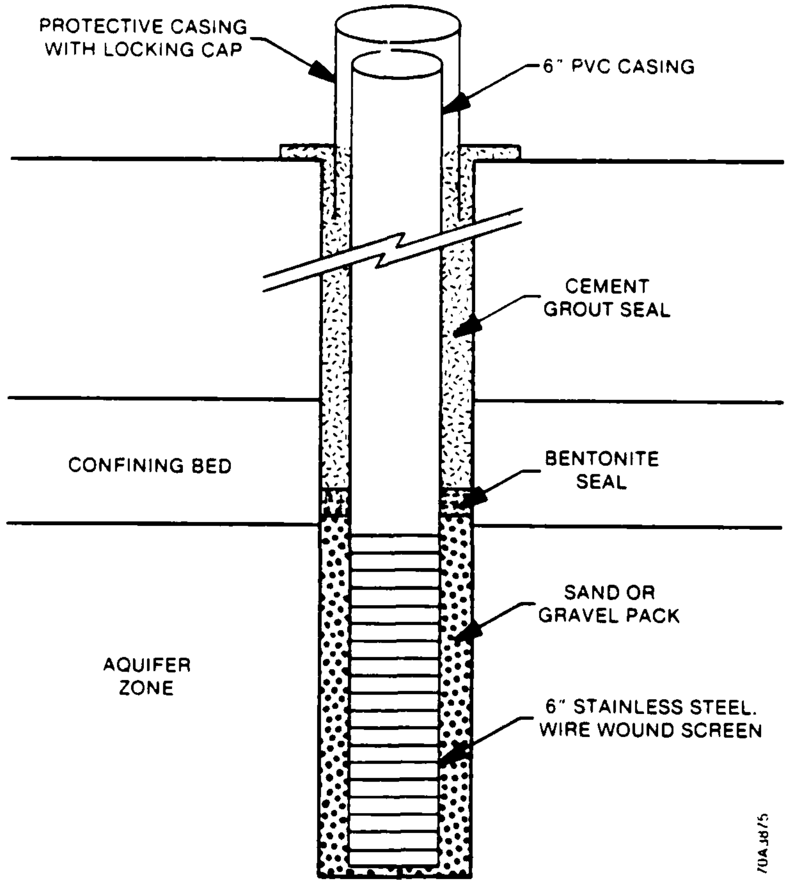

Figure 3.6-1. Schematic Diagram of Aquifer Test Pumping Well

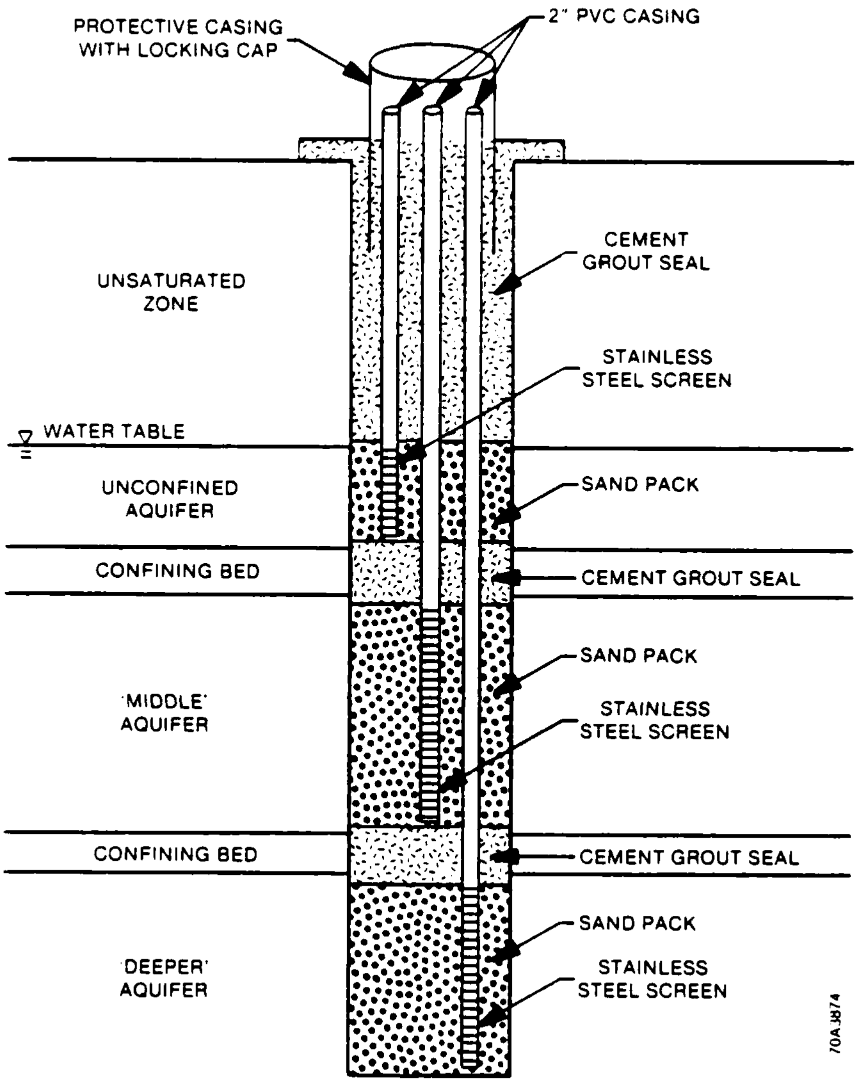

Figure 3.6-2. Schematic Diagram of Aquifer Test Well Cluster.

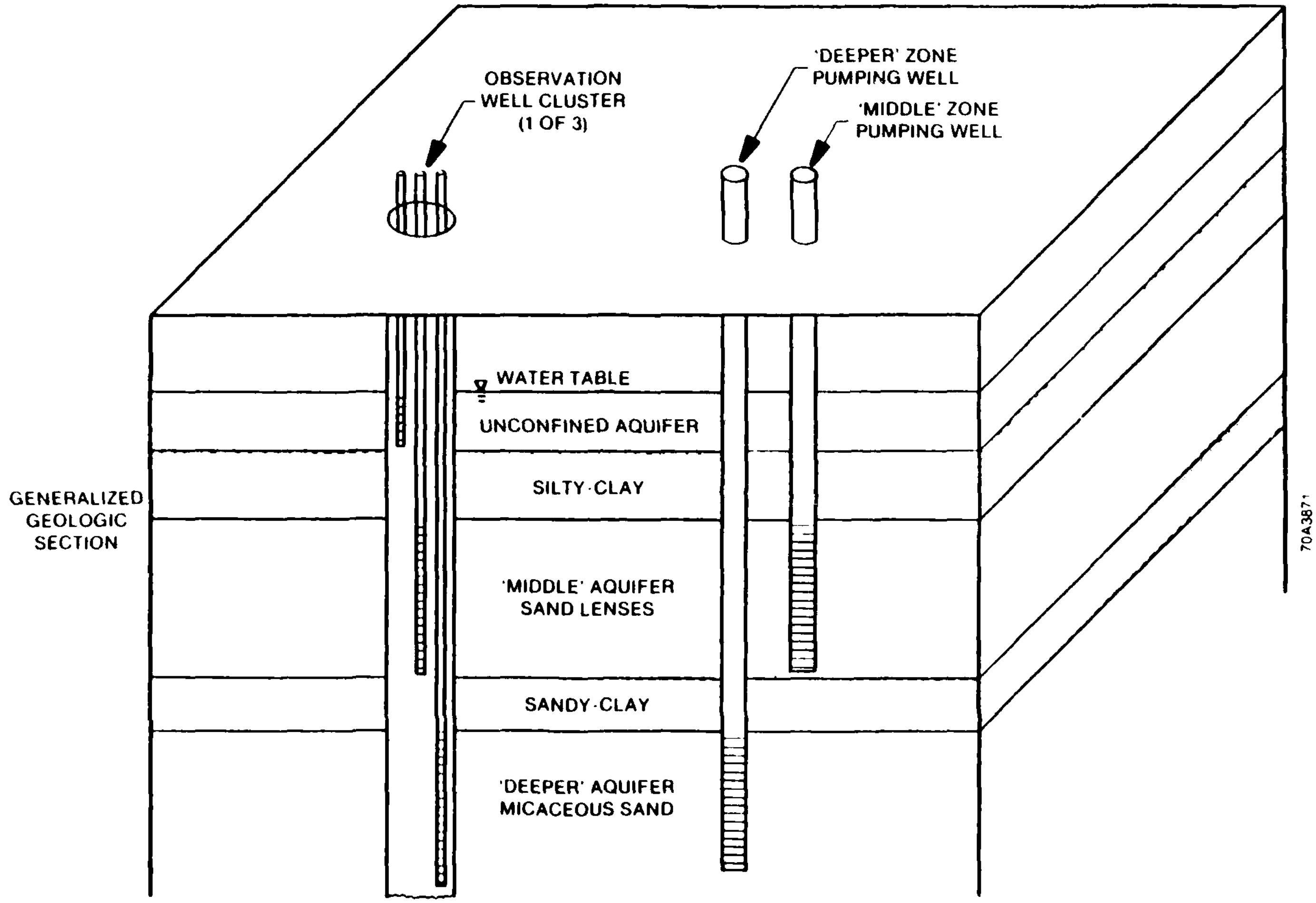

Figure 3.6-3. Simplified Geologic Block Diagram Showing Placement of Aquifer Test Wells

- o Time vs. drawdown data for observation wells in adjacent zones,
- o Pumping rate, and
- o Water discharge parameters including temperature, pH, and conductivity.

These data will be analyzed to solve for aquifer parameters including:

- o Transmissivity (T) - the rate at which water will flow through a vertical strip of an aquifer of unit width, under a hydraulic gradient of one.
- o Storativity (S) - the volume of water released from storage per unit surface area, per unit change in head.
- o Leakage Factor - a measure of the amount of leakage into a semiconfined aquifer, from adjacent aquifers, under pumping conditions.
- o Anisotropy - variability of T and S in different horizontal directions.

Solution for these parameters will provide an understanding of the hydrologic system in the vicinity of Area D and will provide numeric input for modeling tasks. The actual solution methods to be used will be selected based on system response. These methods may include steady-state or non-steady-state solutions for unconfined, confined, or leaky aquifer conditions.

3.6.3.2 Short-Term Aquifer Testing

Although the comprehensive pumping test will characterize the aquifer(s) near Area D, it will be difficult to extrapolate these data to all areas around the base. The extremely variable geology will necessitate that aquifer tests also be conducted in other areas. It is Radian's recommendation, however, that adequate characterization of other areas can be obtained by conducting 'single-well' tests which will yield estimation for the aquifer parameter transmissivity. Storativity, leakage factor and anisotropy terms cannot be reliably quantified by this testing method but a comparison of geologic logs and other aquifer parameters between the single-well tests and the comprehensive test should provide adequate estimates.

The single-well test will be conducted after each monitoring well is installed in the off-base area. Each well will be developed then pumped at a constant rate while measuring the water level drawdown in the well. For wells which do not yield sufficient volumes of water for pumping, clean, potable water will be injected into the well. The decline in water level in the well will then be monitored.

The time vs. drawdown data from single well pumping, or time vs. water-level decline from single well 'slug' testing will be evaluated to determine aquifer transmissivities.

3.6.4 Conclusions

It is concluded from the Aquifer Test Planning task that the combination of a comprehensive aquifer test near Area D and the single-well testing of up to 50 monitoring wells around the base will yield a good understanding of aquifer characteristics and will allow design of effective remedial actions and numeric input to aquifer modeling.

3.7 Task 7. Selection of Well Construction Technology

For this task, Radian reviewed available monitor well drilling and construction technologies and selected the most appropriate method for use in the McClellan AFB investigation.

3.7.1 Objective

The objective of this task was to select monitor well drilling and construction method(s) that best meet the following criteria:

- Ability to reliably determine the occurrence of aquifers during drilling.
- Ability to accurately place monitor well screens at desired depth(s).
- Availability of competent drilling firms to employ the technology.
- Ability to meet all local, state, and EPA requirements for well construction and development procedures.
- Speed and overall reliability of the technology.

Once a technology was selected, a detailed description of the selected technology and contemplated procedures was developed.

3.7.2 Approach

The general approach to the task was to:

- o Interview area drillers as to accepted local practice and equipment availability;

- Screen available technologies with regard to their ability to meet the selection criteria; and

- Select the most appropriate technology.

The bases of the screening and selection were:

- Radian experience in monitor well installation;

- References on well drilling practice, such as Campbell and Lehr (1973);

- Monographs and guidance documents on ground-water monitoring, such as Fenn, *et al*., (1977) and Scalf, *et al*., (1981).

Driller Consultation and Review of Area Drilling Practices

As discussed in Section 3.2, drilling/completion logs were obtained for the general study area. Before assimilation into the Site-Specific database, the logs were reviewed for the identification of drillers with experience in the area and methods locally employed for well drilling and construction. A total of about 390 well logs were reviewed; some of the more recent logs reviewed were for wells just outside the limits of the study area. From the logs, the names of 41 drillers who installed wells in the area were identified.

To gain a better understanding of drilling practices and conditions in and around McClellan AFB, an attempt was made to contact drillers who had installed the greatest portion of wells in the area. Several of the drillers who were identified as having significant experience in the area could not be found in current telephone directories, had changed addresses, or were not available, and thus were not contacted. Several additional drilling firms which had on-base experience or were identified by Radian were also contacted.

From interviews of drilling personnel and water well driller's reports, water well drilling methods employed in the area of McClellan AFB include rotary, auger (boring) and cable tool (percussion method). These drilling methodologies are described in the following sections.

From the water well driller's reports, the most common method used for the completion of domestic (private) wells in the area of McClellan AFB consists of completing the well within the first significant water-bearing strata encountered during drilling. In many cases, steel casing was driven into a clayey layer just above the water-bearing strata. The objective of the steel casing was to provide a shallow formation seal. The borehole below the casing was often left open to serve as the zone of production. Because of the regional decline in ground-water elevations in the McClellan AFB area, many shallow wells in the area have been abandoned or redrilled.

Completion methods for municipal or high-capacity production wells in the area of the base vary, but mainly consisted of casing the entire wellbore with blank pipe and screens at appropriate intervals. Depending on the type of drilling method employed, gravel packs and grout seals were emplaced in the well annulus (between the casing/screen and the formation) at appropriate intervals.

<u>Available Drilling Technologies</u>

As discussed earlier, Radian contacted area drillers to determine equipment availability. Drilling technologies available within reasonable deployment distance of Sacramento are:

- Continuous flight auger;
- Cable-tool; and
- Rotary drilling equipment.

These technologies are discussed below.

Continuous-Flight Augering

Continuous-flight augering equipment employs a helical steel drill tool that is rotated to advance the boring and lift formation materials (cuttings) to the surface. Major variations are hollow-stem and solid-stem augers.

Hollow-stem augers have a cylindrical opening in the core of the drill string. The hollow-stem allows the insertion of sampling tools and well completion materials with the drilling stem in place within the bore hole. Solid-stem augers, on the other hand, have no center opening. These augers are of little utility to anything but shallow sampling operations or shallow well emplacements. Because solid-stem augers must be withdrawn prior to the emplacement of well completion materials, potential borehole caving problems may result.

Hollow-stem augering operations can be performed with or without drilling fluids. Hollow-stem augering is most commonly performed without the use of fluids during environmental investigations. If used, drilling fluids are normally circulated down through the hollow-stem of the augers to return to the surface through the annulus. Augering with the use of fluids can decrease boring wall friction and/or increase cutting return efficiency. The use of fluids can increase the maximum depth of augering. Drilling fluids commonly employed for augering operations include clear water (water with no additives), water with synthetic natural additives and compressed air. The use of drilling fluids for augering may increase drilling efficiency, but because foreign fluids are introduced into the borehole, the chemical integrity of formation(s) to be sampled may be affected. The chemical effect of drilling fluids can, in most cases, be considered negligible if a chemically compatible drilling fluid is employed and/or the well is properly developed and purged prior to sampling.

Development and purging time requirements may be significantly increased when drilling muds are employed. Another possible disadvantage to the use of drilling fluids during augering operations is that fluids may hinder identification of the zone of first saturation. The use of fluids may cause the saturated zone to be obscured during drilling, thereby resulting in improper screen placement.

Compressed air can be employed for hollow-stem augering drilling operations. Compressed air can increase cutting return efficiency and possibly increases the maximum depth of drilling. The use of compressed air is not as common as the use of liquids for augering, although the chemical integrity of the boring may be better preserved through the use of air instead of liquids. In addition, compressed air should not significantly affect the identification of the first zone(s) of saturation. However, the use of compressed air during auger drilling is probably not necessary in the vicinity of McClellan AFB.

Cable Tool

Cable-tool drilling equipment normally employs a cutting tool which is repeatedly lifted and dropped to break up the material at the bottom of a boring. Periodically, a bottom-fill bailer is used to remove the cuttings from the hole. Formation samples are normally collected from the bailed cuttings. Normally, steel casing is driven as drilling proceeds. A common synonym for this technology is "percussion drilling."

The use of cable tool methods for well construction may require the introduction of fluids into the borehole to facilitate bailing operations in non-water-bearing strata. The use of chemically compatible fluids can reduce the possible chemical effects of introducing fluids to the borehole. The use of fluids for bailing may obscure the identification of the first zone of saturation.

Drillers in the area of McClellan AFB report that during percussion drilling, little or no caving occurs and that drilling may often be conducted in an open hole below surfical deposits. Several of the drillers contacted speculated that the wall smearing effect and the tool-to-boring wall impact during cable-tool drilling imparted stability to the boring walls. The apparent lack of slumping during cable tool drilling may also be attributable to the natural stability of the formations as reported by several area drillers employing other drilling methods.

Rotary Drilling

Rotary drilling employs a steel bit which is rotated at the bottom of a boring to break up the material. Air or liquids (water, with or without additives) is circulated down the borehole to cool and lubricate the bit and to remove cuttings. Formation samples are normally collected from the fluid cuttings stream. Major variations of this method involve the nature of the circulating fluid.

Conventional rotary methods employ the use of a circulating fluid that is a mixture of water and bentonite clay. The resulting "mud" is denser and more viscous than water to aid in holding the boring open and lifting cuttings. In some cases, the bentonite is replaced with guar bean extract (UOP Johnson brand REVERT). This product consists of long-chain vegetable matter which increases viscosity of the fluid but biodegrades for easier well development. In addition, water alone can also be used as the circulating fluid, especially if the formations encountered contain clay. Conventional rotary is the most common water-well drilling technology.

Air rotary methods employ air as the circulating fluid. The air stream is produced by a high-capacity compressor. In some cases, small amounts of water or water with a surfactant (foaming agent) are injected into the air stream to aid in lifting cuttings. The technology may be used as either direct (open hole) or with simultaneous casing drive depending on drilling conditions encountered. Temporary casing can be driven during

drilling to reduce/eliminate vertical movement of ground water in the borehole and to prevent borehole collapse during drilling and completion activities.

An important variation of the air-rotary technology is the dual-tube air-rotary system. For this system, the drill string consists of two concentric steel tubes. The center tube is a conventional drill stem; the outer one is a heavy steel cylinder which is slightly smaller than the drill bit. Air is injected between the two tubes to lift cuttings through the center of the drill stem. This was the technology utilized for the reconnaissance borings at McClellan AFB during this study.

3.7.3 Results

Once the available technologies were identified, they were screened for the selection of candidate methods for subsequent monitor well installations at McClellan. Each of the candidate technologies was evaluated in detail. The results of the evaluation are presented below. A summary of the evaluation is listed in Table 3.7-1.

Based on the relative merits and demerits of each selected drilling methodology displayed in Table 3.7-1, Radian selected two technologies most likely to prove successful and environmentally acceptable for monitor well completions at McClellan AFB. These were:

- Hollow-stem auger for shallow monitor wells of depths less than 120 feet. This is the probable depth capacity for hollow-stem augering based on locally available drilling equipment and the use of 12-inch outside diameter, 8-inch inside diameter hollow-stem augers. The emplacement of larger casing, if required, will necessitate the use of larger diameter augers, thereby reducing the maximum depth of drilling.

- Air rotary with casing drive for deeper wells.

TABLE 3.7-1. RELATIVE MERITS OF IDENTIFIED DRILLING TECHNOLOGIES

Technology	Advantages	Disadvantages
Hollow-stem Auger (no fluids except for clean water to be used to "punch out")	Rapid, economical, reliable, provides for accurate logging and well placement, suited for identification of "first" water.	Generally limited to relatively shallow depths and unconsolidated materials. Well diameters are usually limited to 4 inches or less. Reduced maximum drilling depths occur if large augers are employed. Augering is usually performed in an open hole, thus vertical movement of groundwater in borehole may be of concern where multiple water bearing zones are encountered. Not well suited for drilling in areas where large debris or boulders are encountered during drilling.
Cable-tool	Reliable, provides for accurate logging and well placement.	Slow, relatively expensive (for environmental studies)
Coventional Rotary	Rapid, reliable, relatively inexpensive.	Logging is imprecise without the use of down-hole geophysical methods. Successful monitor well placement and development are often difficult. Vertical movement of ground water within the borehole is possible.
Air Rotary with Casing Drive	Rapid, reliable, provides for accurate logging and well placement. Driven casing reduces/eliminates vertical movement of ground water within boring.	Relatively expensive, temporary steel casing must be withdrawn to meet monitor well construction requirements. Air-rotary methods employing casing drive are usually very noisy.

In addition to the selection of an appropriate drilling technology, materials for screens and casing were also evaluated and selected. The selection of appropriate materials for monitor well casing and screen was performed as part of Task 8. The results of that study are quoted here for completeness.

There appears to be a concensus among investigators as to the relative merits of materials for well screens and casing. General findings are summarized in Table 3.7-2.

TABLE 3.7-2. MATERIAL SUITABILITY SUMMARY WELL SCREENS AND CASING

Material	Advantages	Disadvantages
Rigid PVC	Rugged, durable, immune to inorganic corrosion, relatively inexpensive.	Subject to attack by chlorinated or other organic solvents.
Teflon™	Fairly durable, immune to nearly all chemical attack.	Relatively expensive.
Stainless Steel	Rugged, durable, immune to organic attack, reasonably immune to inorganic chemical attack (other than high concentrations of chlorides).	Relatively expensive.

™Teflon is a registered trademark of the E.I. DuPont de Nemours Company.

Many investigators and advisors (Nacht, 1983; Scalf, et al., 1981; among others) suggest that rigid polyvinyl chloride (PVC) casing and screen is "probably acceptable," although most add qualifiers such as, "if wells are suitably purged." Some also suggest that the long-term effects of PVC expo-

sure to dilute solutions of chlorinated solvents are not well known. Since these sources expressed concern for the suitability of PVC, use of this material for the McClellan AFB study carries some risk. Upon evaluation, the cost differential between stainless steel and PVC is not excessive (see Section 3.8). Therefore, stainless steel, the higher cost but more reliable material, has been chosen for the well screen and wetted casing material.

Teflon™ was also considered as a casing/screen material. The major cause for selection of Teflon™ over stainless steel would be the presence of inorganic constituents which would attack metal. The principal ion of concern is chloride. Ground-water quality at McClellan AFB is generally good. Chloride concentrations were noted to vary between 13 and 44 mg/L in ground-water samples collected during the reconnaissance boring effort. The average concentration of chloride in the samples was calculated at 17 mg/L (CH2M Hill, 1981) and 20 mg/L in the reconnaissance borings. Therefore, there appears to be no compelling reason to employ Teflon™ in this case.

3.7.4. Conclusions

Available drilling technologies were screened to determine the most appropriate for use in the off-base monitoring well program at McClellan AFB. Technologies given serious consideration were:

- Hollow-stem auger;
- Cable-tool;
- Conventional rotary; and
- Air rotary with casing drive.

Of these, hollow-stem auger was selected for the emplacement of shallow wells to depths up to 120 feet. Air rotary with casing drive was selected for the emplacement of deeper monitor wells. Stainless steel was selected as the appropriate material for screen and wetted well casing. An explanatory narrative of contemplated well drilling and installation procedures is provided in Appendix 7-A.

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3.8 Task 8. Sampling Material Study

This task is part of Action 5--Well Sampling Equipment and Strategy. The overall purpose of the action is "to review ground-water sampling [procedures] and equipment and determine the appropriate system to be installed for monitoring wells while at the same time define a sampling strategy to be used in the McClellan AFB effort." The action consists of three tasks:

- Task 8: Sampling Material Study
- Task 9: Sample Equipment Design
- Task 10: Sampling Protocol

For the sampling material study, Radian reviewed existing studies of the effects of tubing on sample integrity and determined the most appropriate type of material for use in sampling equipment. The investigation consisted of evaluating case histories of ground-water monitoring programs (particularly with contamination by volatile organic compounds), acquiring information from manufacturers and vendors of sampling equipment and examining the long-term requirements of equipment durability at McClellan AFB.

3.8.1 Objectives

The objective of the sampling material study was to identify materials suitable for use in the ground-water monitoring program at McClellan AFB. Materials of construction for the sampling equipment should:

- Be rugged and durable enough to withstand prolonged usage;
- Withstand chemical degradation from chemical compounds present in the ground-water system; and

- Neither contribute nor remove contaminants of interest from the sample stream.

The approach discussed below is designed to identify and select materials meeting these criteria.

3.8.2 Approach

The primary approach to the issue consisted of an extensive literature review. Principal sources were:

- Recent journal articles on materials for sampling;
- Monographs on sampling procedures and materials; and
- EPA guidance documents on ground-water sampling.

In order to assemble a suitable database, recent review articles and the Radian library holdings were used to identify citations to original references. Several recent review articles (Barcelona, et al., 1983; Curran and Tomson, 1983; Nacht, 1983) contained extensive bibliographies, so a suitable amount of data was readily obtained. For each data source reviewed, the materials evaluated were tabulated, along with advantages and disadvantages of each.

Initially, data on any material or class of materials evaluated in the literature were tabulated. Materials fell into the following classes, which were maintained for the evaluation process:

- Teflon™;
- Stainless steel;

- Rigid polyvinyl chloride (PVC); and

- other plastics.

Materials for Well Screens and Casing

Since the selection of materials for sampling is closely related to the selection of materials for well casing and screens, initial attention was directed to selection of materials for monitor well construction. Materials considered were:

- Rigid, threaded polyvinyl chloride (PVC);

- Stainless steel; and

- Teflon™.

The following materials, commonly accepted as unsuitable for monitor well construction, were not evaluated:

- Solvent-welded PVC and

- Galvanized or other mild steel.

Materials for Sampling Devices

Many of the considerations applicable to casing and screens also apply to materials for sampling devices. These materials must neither add nor subtract contaminants from the sample stream. They should be essentially immune to chemical degradation by compounds present in the ground water. In addition, materials for sampling devices must be easily cleaned or decontaminated.

Some portions of sampling devices (e.g., tubing) are designed to be flexible. However, many flexible plastics contain plasticiers or extenders which "bleed" or which render the materials porous and permeable to contaminants, especially to small molecules. In order to avoid these problem areas, consideration was given only to "true polymers," such as polypropylene, polyethylene, Viton™, silicone and neoprene. These flexible plastic formulations were considered in addition to the materials researched for well casings.

The results of these data gathering and evaluation procedures are discussed below.

3.8.3 Results

Materials for Well Screens and Casing

There appears to be a concensus among investigators as to the relative merits of materials for well screens and casing. The general findings of the complete literature review are summarized in Table 3.8-1, below.

TABLE 3.8-1. MATERIAL SUITABILITY SUMMARY
WELL SCREENS AND CASING

Materials	Advantages	Disadvantages
Rigid PVC	Rugged, durable, immune to inorganic corrosion, relatively inexpensive.	Subject to attack by chlorinated or other organic solvents.
Teflon™	Fairly durable, immune to nearly all chemical attack.	Very expensive.
Stainless Steel	Rugged, durable, immune to organic attack, reasonably immune to inorganic attack (except for high chlorides).	Relatively expensive

™Teflon is a registered trademark of the E.I. DuPont de Nemours Company.

Many investigators and advisors (Nacht, 1983; Scalf, et al., 1981; among others) suggest that rigid PVC is "probably acceptable," although most add qualifiers such as, "if wells are suitably purged." Some also suggest that the long-term effects of PVC exposure to dilute solutions of chlorinated solvents are not well known. Since these sources expressed continued concern for the suitability of PVC, use of this material at McClellan AFB carries some risk. Upon evaluation, the cost differential between stainless steel and PVC is not excessive. Using cost data from one supplier, the differential in materials cost is only $450 per well. Therefore, the higher cost, but more reliable stainless steel has been chosen for the well screen material.

The major cause of selection of Teflon™ over stainless steel would be the presence of inorganic constituents which would attack the steel. The principal ion of concern is chloride. The ground-water quality at McClellan AFB is generally good, with chloride concentrations of about 17 mg/L (exploratory borings) to 18 mg/L (CH2M Hill, 1981). Therefore, there would appear to be no compelling reason to select the higher cost material.

Materials for Sampling Devices

As stated above, many of the considerations applicable to casing and screens also apply to materials for sampling devices. The concensus among investigators is the same concerning rigid materials for sampling devices. Therefore, the same findings are applicable.

There are relatively little data concerning variations among flexible materials. Curran and Tomson (1983) found organics leaching from common plastics in the following order of increasing leachability:

- Teflon™
- Rigid PVC (nonglued)

- Polyethylene
- Polypropylene
- Rigid PVC (glued)
- Flexible PVC

Barcelona, et al. (1984) found Teflon™ to be the most desirable flexible material, followed by either polypropylene or linear polyethylene. They do not recommend flexible PVC for organic monitoring programs. They further suggest that other polymeric plastics, such as Viton,™ neoprene, and silicone rubber (materials for bladders, gaskets, and tubing) be used cautiously with controlled exposure trials. This caution was apparently based more on lack of data than on hard evidence, since later discussions suggest that Viton and medical grade silicone are acceptable where performance requires a more elastic material. These are the only specific research-grade evaluations of flexible materials that were revealed in the literature search. Most guidance documents recommend the most stringent criteria for sampling appliances, since the sample has the most intimate contact with the device. For example, Scalf, et al. (1981) recommend Teflon™ or glass for trace-level organic sampling.

Based on these findings, the flexible portions or sampling devices, if any, can safely be fabricated of Teflon™ with the polymer plastics, with silicone or Viton utilized as necessary (such as for O-rings or bladders).

3.8.4 Conclusions

Based on the above considerations, Radian makes the following recommendations concerning materials for ground-water sampling at McClellan AFB:

- Well Screen: Stainless steel, with blank stainless steel casing to 10 feet above the top of the screen.

- Well Casing: Schedule 80 Polyvinyl chloride (PVC) above the screen and stainless steel blank.

- Sampling Pumps: Stainless steel and/or Teflon™, with silicone or Viton, as required.

- Sample Discharge Lines: Teflon™.

3.9 Task 9. Sample Equipment Design

This task is part of Action 5 - Well Sampling Equipment and Strategy. The overall purpose of the action is "to review ground-water sampling [procedures] and equipment and determine the appropriate system to be installed for monitoring wells while at the same time define a sampling strategy to be used in the McClellan AFB effort." The action consists of three tasks:

- Task 8: Sampling Material Study
- Task 9: Sample Equipment Design
- Task 10: Sampling Protocol

For the sampling equipment design, Radian received the following guidance from USAF/OEHL:

> Present a comparison of well dedicated systems vs. portable monitoring systems, including man-hours needed to retrieve the sample, and cost comparisons of the systems. Present the advantages and disadvantages of each system. A key factor in the acceptability of a sampling system is its ability to provide synoptic measurements across the site. The materials (e.g., stainless steel vs. Teflon vs. PVC) for equipment, sample collection methods (surface pump, bailer, submersible pump, gas lift), and water handling techniques shall all be considered in the design of a monitoring system. All monitoring systems proposed shall meet the requirements of state and regulatory agencies.

3.9.1 Objective

The objective of this task is to select and design an appropriate sample retrieval technique for the McClellan AFB monitoring program. The

requirement is for a system which will be simple, reliable, and easy to operate, which will require a minimum of manpower and which will provide adequate sampling effectiveness in terms of bias, and the potential of cross-contamination. The system must also provide samples in a relatively synoptic manner. Given systems which meet these criteria, the least-cost system will be chosen.

3.9.2 Approach

For purposes of selection and design, ground-water sampling equipment can be divided into two broad categories--dedicated and portable. The approach for this task consisted of an initial screening to identify the most suitable equipment for dedicated or portable use, then evaluating these two systems in comparison with one another. Major sampling strategies considered were:

1. Installed (dedicated) pumps
   - Conventional submersible
   - Bladder pump
2. Portable pumps
   - Conventional submersible
   - Bladder pump
   - Reciprocating piston, air drive

This review and screening was based on manufacturer's literature, interviews with manufacturer's representatives and Radian experience in installing and sampling ground-water monitoring systems. After the initial screening was completed, the suitability of the remaining systems to meet the technical monitoring needs of the program were evaluated on the basis of recent definitive work by Barcelona, et al. (1984) and general sampling guidance, such as Fenn, et al. (1977).

Certain well purging equipment, such as air-lift pumps and conventional bailers, were not evaluated in depth. These systems are unsuited to long-term monitoring for volatile substances and did not merit consideration.

After initial consideration, conventional submersible pumps were dropped from consideration, based on the relatively low-volume purging requirements. Since the majority of the wells will be completed near the top of the saturated zone, casing volumes are low and pumping will take place from near the well screens. Even a relatively small submersible will have a large (several gallons per minute) flow rate, which evacuates the well quickly, but requires manually controlled cycling to prevent motor burnout. High production rates will also induce excessive sediment production from even properly developed wells. This sediment can jam pump impellers or accumulate in the well, reducing its productivity. Moreover, light-duty pumps have plastic impellers which can interfere with contaminants of interest in the discharge stream.

One other ground-water sampling technology was evaluated for use at McClellan AFB. This technology utilizes porous-walled sample vessels emplaced directly into the aquifer material in an open borehole, which is then backfilled. Samples are collected by pressurizing the vessel with an inert gas, such as nitrogen. Examples of manufacturers are Barcad and Geo-Mon. These units are particularly suited to multi-level installation in deep aquifers. However, since they depend upon significant submergence below the water table for efficient operation and expose the sample to the driving gas, they were deemed unsuitable for the present purposes.

Therefore, for the portable system, the choice remained between a portable bladder pump and portable reciprocating piston pump. Both are air driven, but do not release air into the well column. Either is a completely suitable device for purging. For either choice, the well would be purged with the portable pump and the sample collected with a Teflon™ bailer. This reduces the requirement for decontamination between wells and reduces the probability of cross contamination. Barcelona, et al. (1984) found that a

conventional bailer of suitable material was actually superior to a more sophisticated device, such as a syringe, for volatile sample capture. A satisfactory alternative is a small diameter Kemmerer bottle (thief sampler), fabricated of stainless steel and Teflon™.

Based on Radian experience and consideration of the available equipment, the portable reciprocating piston pump (manufactured by Bennett Pump Co.) is the equipment of choice. Since the system will be operated from a fixed base and be vehicle mounted, the lack of hand-portability of the piston pump system is not a drawback. The ease of deployment of the Bennett pump makes it the obvious choice.

For the dedicated (installed) system, the equipment of choice is the air-operated bladder pump.

For the detailed evaluation, an estimate of capital versus operating costs was made, considering sampling and decontamination time with both systems in comparison with the initial cost of the two systems. Items common to both, such as an air compressor, tanks for containing purge water and transit time from well to well, were not considered, since they do not affect the choice of sampling strategy.

From an operational standpoint, the dedicated system has certain advantages. No time is required for deploying or retrieving the pump or for decontamination between wells; the amount of equipment to be taken to the field is reduced; and the required skill level is lower. On the other hand, a dedicated system is inflexible and cannot be readily modified to meet changing conditions or new monitoring needs. If a dedicated pump fails, or sampling conditions change (e.g., lowered water level) such that suitable samples are not being recovered, the pump must be pulled and repaired or modified to adjust to new conditions. A portable system is an inherently flexible one, albeit requiring greater labor expenditures and a somewhat higher skill level for the operators. If a sampling program changes (e.g., a change in water levels or wells to be sampled), a portable system can be used

directly without adaptation. A dedicated system would be modified by installing new equipment. The initial choice of sampling equipment will be made on the basis of expected costs, with qualitative adjustments, as required, to reflect anticipated overall system suitability.

The constraints and parameters of evaluation are as follows:

- The ground-water monitoring system will be in place and operating for a period of 30 years. The frequency of sampling will be quarterly for the first two years of operation, annually thereafter.

- The system is assumed to consist of 50 wells. An array of 50 can be sampled in three to four weeks, which will satisfy the requirement for synoptic observations. If the actual system is larger, additional sampling units would be deployed in order to maintain relatively short total sampling time frames. Thus, for a 100-well system, the complete cost estimate would be doubled, but the relative merits of portable versus dedicated systems would remain unaltered.

- The Air Force desires to minimize the labor required for the sampling program.

- Reasonable skill and prudence on the part of the sampling team is presupposed. That is, the system will be designed to be as simple and reliable as possible, but there is no requirement for extraordinary measures to simplify the operation.

- For the dedicated pump system, the following items of equipment will be required:

  -- per well--pump, air and sample tubing bundle and well cap--total cost $673.

  -- per system--control unit--total cost $1,695.

- For the portable system, the following items of equipment will be required:

  -- portable sampling unit--total cost $3,285.

  -- Teflon™ bailer and stainless steel cable--total cost $245.

- Current equipment acquisition costs (capital costs), are loaded at 23.3% general and administrative cost. Future equipment costs are unloaded.

- For both systems, the following replacement schedule has been assumed:

  -- Dedicated system--replacement of complete pump and tubing assembly ($673) at ten year intervals.

  -- Portable system--replacement of tubing bundle ($900) and rehabilitation of pump ($149 factory servicing) at five year intervals.

- Labor costs have been assumed at the following rates:

  -- Air Force labor--Staff Sergeant, E-5, $15.25 per hour ($31,851 per annum, Myers, 1984).

-- Contract labor--mid-level technician or junior professional, $27.00 per hour.

- The effects of inflation, per se, are not addressed. The time cost of money is addressed by assuming a 10% interest rate for reducing all cost elements to present cost.

- The total sampling time per well will be one hour for the dedicated system, two hours for the portable system. This includes setup, purging, and sample collection. For the portable system, it also includes time to deploy, retrieve and decontaminate the pump and bailer. These time measures are based on Radian Corporation's experience in operating monitor well networks.

The cost calculations are presented in detail in Appendix 9. Cost elements are summarized in Table 3.9-1, rounded to the nearest dollar. Current capital costs are presented for both systems. Future operations and maintenance costs are estimated for the thirty-year period and discounted to present value, utilizing a 10% annual percentage rate.

TABLE 3.9-1. COST COMPARISON--PORTABLE VS. DEDICATED SYSTEMS
(100-Well Systems)

	Portable System		Dedicated System	
Cost Item / Labor Source	USAF	Contract	USAF	Contract
Original Equipment	$ 8,705	$ 8,705	$87,161	$ 87,161
Repair/Replace Equipment	3,118	3,118	35,945	35,945
Sampling Labor	49,097	86,926	24,548	43,463
TOTAL	$60,920	$98,749	$147,654	$166,569
$ Difference (Dedicated-Portable)			$86,734	$ 67,820

3.9.3 Results

The available ground-water sampling equipment has been evaluated and optimal equipment selected for use in the McClellan AFB monitoring program. Candidate portable and dedicated systems were then compared to discover the least-cost strategy.

For a nominal 50-well monitoring array, an optimum portable ground-water sampling system has been compared to an optimum dedicated system. The comparison was based on initial capital costs and on the present value of future operation and maintenance costs. Labor costs for both an Air Force-staffed and a contract-staffed operation were used. Both systems are judged capable of providing satisfactory ground-water quality data over the life of the project, given ordinary skill and prudence on the part of the operating staff.

On the basis of the cost comparisons made, the portable system is the least-cost alternative. The differential for a 100-well system is approximately $87,000 (Air Force labor), or $68,000 (contract labor). In order to put these estimates in the context of total system costs (as opposed to comparing only those components which vary for the two alternatives), the following preliminary estimates of common cost elements are presented:

- Capital cost (exclusive of vehicles) and equipment maintenance - $5,000.

- Operating labor - $12,000 (Air Force); $22,000 (contract).

It is emphasized that these figures are very loose estimates, provided only to place the cost comparisons in the context of total system costs.

The cost comparisons, including equipment and labor common to both systems, are shown on Table 3.9-2. All costs are rounded to the nearest $100.

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TABLE 3.9-2. TOTAL SYSTEM COST COMPARISONS
(100-Well Systems)

Cost Item / Labor Source	Portable System USAF	Portable System Contract	Dedicated System USAF	Dedicated System Contract
Equipment	$21,800	$ 21,800	$133,100	$133,100
Labor	73,100	130,900	48,500	87,500
TOTAL	$94,900	$152,700	$181,600	$220,600
$ Difference			$86,700	$ 67,900
% Increase			91	44

On the basis of these considerations, one is led to select the portable system as the more cost-effective. However, this conclusion is based on the original assumptions used to set up the calculations. In an attempt to evaluate the effect of these assumptions on system choice, two basic assumptions are modified to enhance the desirability of the dedicated system.

Initially, per-sample time for the dedicated system was estimated at one hour; for the portable system, two hours. The first modification is to explore the effects of increasing the portable system sampling time to three hours. The second modification is to explore the effects of a reduction in replacement costs for the dedicated system by increasing the mean life expectancy of the installed pumps from 10 to 15 years.

As can be see. in Table 3.9-3, these two modifications, taken together, bring the estimated cost of a contractor-operated dedicated system only to within rough equivalency with the portable system. The Air Force-operated portable system remains the more cost-effective of the two. In view of these cost considerations and the inherent flexibility of the portable system, Radian recommends that a portable ground-water sampling system be adopted for the majority of the McClellan AFB monitoring program.

TABLE 3.9-3. EFFECTS OF INCREASING PORTABLE SYSTEM SAMPLING TIME TO THREE HOURS AND INCREASING DEDICATED PUMP LIFE TO 15 YEARS (100-Well Systems)

Cost Item / Labor Source	Portable System USAF	Portable System Contract	Dedicated System USAF	Dedicated System Contract
Original Total	$60,920	$98,749	$147,654	$166,569
Additional Sampling Labor	24,548	43,463	-0-	-0-
Reduced Pump Replacement	-0-	-0-	-19,833	-19,833
REVISED TOTAL	$85,468	$142,212	$127,821	$146,736
$ Difference			$42,353	$ 4,524
% Increase			50	3

3.9.4 Conclusions

Optimized dedicated-pump and portable-pump ground-water sampling systems have been designed to support the McClellan AFB monitoring program. Each of these systems is judged capable of providing acceptable samples, given common prudence on the part of the operators. However, there are inherent strengths and weaknesses in each of the systems. Table 3.9-4 contains a description of the systems chosen and lists the relative merits of each.

A detailed life-cycle cost comparison was completed for the two systems, considering initial (capital) costs, repair, and replacement costs and labor for sample collection. Utilizing the most likely scenario for both systems, the portable strategy is the most cost effective. The cost differential is $86,700 for Air Force labor, $67,900 for contract labor for a 100-well system. Utilizing the scenario most favorable to selection of the dedicated system, the portable remains the more cost-effective, although the differentials are reduced to $42,353 and $4,524, respectively. In view of

TABLE 3.9-4. SYSTEM DESCRIPTIONS

Portable System

Bennett™ reciprocating piston, reel mounted, air operated for well purging, followed by use of a conventional bailer of Teflon™ for sample recovery

- -- The system's strengths lie in its flexibility in use and its adaptability to changed circumstances and in its lower initial cost.
- -- The system's weakness lies in its requirement for greater labor input and in a slightly higher required skill level on the part of the operator.

Dedicated System

Well Wizard™ bladder pumps installed in each well for both purging and sample capture, surface control unit.

- -- The system's strengths lie in its ease of operation and low labor requirement.
- -- The system's weaknesses lie in its inflexibility and in its high initial cost.

these cost considerations and the inherent flexibility of the portable system, Radian recommends that a portable ground-water sampling system be adopted for monitoring wells screened in the uppermost saturated zones.

One important departure from the above recommendation will be made for certain on- and off-base monitor wells which do not fit the assumed pattern of wells screened at the water table. It is anticipated that approximately 16 of the off-base monitor wells will be completed at greater depths within the aquifer. Certain on-base monitor wells to be included in the permanent monitoring program are also completed at depths substantially below

the static water level. In all these cases, there will be substantial volumes of stagnant water to be removed from the casing during purging operations (0.65 gals per foot of 4-inch casing). Removal of this water with a low volume (1 gpm) pump would be unnecessarily tedious and time-consuming. The on-base sampling activity demonstrates that this purging can consume many hours for a deep, large-diameter well. This will result in excessive labor costs for these particular wells.

If dedicated pumps were used for these deeper wells, an inflatable packer can be installed just above the pump, isolating the stagnant water in the wellbore. Thus, purging requirements would be limited to the zone below the pump, that is, the screen and a minimal amount of blank casing. Radian recommends that the deeper monitor wells be equipped with dedicated pumps and packer assemblies. Any packer assemblies considered for use will be screened for compatability with potential contaminants. Packers will be of a material that is non-reactive to prevent introduction of target compounds to the monitor wells.

3.10 Task 10: Sampling Protocol

This task is part of Action 5--Well Sampling Equipment and Strategy. The overall purpose of the action is "to review ground-water sampling (procedures) and equipment and determine the appropriate system to be installed for monitoring wells while at the same time define a sampling strategy to be used in the McClellan AFB effort." The action consists of three tasks:

- o Task 8: Sampling Material Study,
- o Task 9: Sampling Equipment Design, and
- o Task 10: Sampling Protocol.

For the Sampling Protocol task, Radian was directed to determine a sampling strategy which shall define the appropriate frequency and methods of obtaining ground-water samples. The following factors shall be used in the development of the sampling strategy: potential seasonal variation and ground-water quality; lateral and vertical changes in lithology; and ground-water flow patterns in the vicinity of McClellan AFB.

3.10.1 Objectives

The objectives of this task were to develop a sampling strategy for the McClellan AFB off-base monitoring program and to initiate development of a sampling protocol for use in the ongoing ground-water monitoring program at the base. This protocol will be fleshed out during the execution of the monitor well installation and initial sampling.

3.10.2 Approach

The general approach to this task was to integrate the findings of previous studies with the planning process contained in the other current tasks. The previous studies addressed are:

- Brunner and Zipfel, 1981,
- CH2M Hill, 1981,
- Engineering-Science, 1983, and
- GAO, 1984.

These studies represent the database at the initiation of the current effort.

For the current effort, several tasks bear on the content of Task 10. The major tasks providing input are:

- Task 9: Sample Equipment Design, and
- Task 13: Monitor Well Siting.

In addition to these other task reports, general guidance documents on development of sampling protocols were utilized for background as follows:

- Barcelona et al., 1983,
- EPA, 1979,
- Fenn et al., 1977,

- Colchin et al., 1978,
- Morrison, 1983,
- Myers, 1984,
- Nacht, 1983, and
- Scalf et al., 1981.

3.10.3 Results

The results of this task are discussed below, under the separate aspects of the program.

3.10.3.1 Sampling Equipment

In Task 9, the available ground-water sampling equipment was evaluated and optimal equipment selected for use in the McClellan AFB monitoring program. Candidate portable and dedicated systems were then compared to discover the least-cost strategy.

For a 100-well monitoring array, an optimum portable ground-water sampling system was compared to an optimum dedicated system, based on initial capital costs and on the present value of future operation and maintenance costs. Both systems were judged capable of providing satisfactory ground-water quality data over the life of the project, given ordinary skill and prudence on the part of the operating staff. On the basis of the cost comparisons made, the portable system is the least-cost alternative.

For the portable system, the equipment of choice was a portable reciprocating piston pump (manufactured by Bennett Pump Co.). The well would be purged with the portable pump and the sample collected with a Teflon™ bailer. This reduces the requirement for decontamination between wells and reduces the probability of cross contamination.

For the portable system, the following items of equipment will be required:

- o Portable sampling unit (Bennett Model 180-125 or -250 with Teflon™ discharge tubing);
- o Teflon™ bailer and stainless steel cable;
- o Air compressor;
- o Decontamination equipment and supplies;
- o Holding tanks for purge and wash water;
- o Field analytical instrumentation (pH and conductivity meters, thermometer, water level indicator); and
- o Vehicle for transportation of system.

3.10.3.2 Monitor Well Array

It is assumed that the monitor well array at McClellan AFB will consist of 100 wells; 50 on-base monitoring wells installed during previous efforts and 50 off-base monitoring wells to be installed.

The 50 on-base wells will be selected in the next stage of activities based upon evaluation of their position, construction, and the results of a well redevelopment task.

The 50 off-base wells are currently planned to be installed in two phases: 30 wells in the first phase and 20 wells in the second phase (see Section 3.13).

3.10.3.3 Analytical Schedule

Based on our current knowledge of the system, the primary parameters to be addressed in a long-term ground-water monitoring program are all contained within the list of compounds for EPA Method 601 (Purgeable Halocarbons by gas chromatography). This decision may need to be revised after the results of the on-base sampling are available.

It is recommended that during the sampling program, sufficient water samples should be obtained to analyze for organics by EPA Method 601 and to provide a "back-up" sample for gas chromatography-mass spectroscopy analysis (EPA 624/625). By this method, the less expensive EPA 601 method may be used as a "screening" analysis and, if compounds of particular concern are identified or if the results of a 601 analysis are questionable, the GC-MS analysis can be conducted for confirmation.

The frequency of sampling will vary, both with the requirements of the regulatory agencies and with the observed variation in concentrations. Initially, it is anticipated that a quarterly sampling schedule will adequately address temporal variations in concentration. More frequent sampling is not merited on a technical basis.

After sampling data for a full year are available, the frequency of sampling should be reviewed. There is every reason to believe that the frequency of sampling can be reduced to one per year, for some monitoring wells.

3.10.3.4 Sampling Protocol

As discussed above, the development of the full sampling protocol will await completion of the monitor well network and the initial sampling and analysis from all wells. The protocol will contain:

- Equipment operation and maintenance;
- Sample bottle preparation, sample collection, and handling;
- Chain of custody and similar procedures;
- Required laboratory procedures; and
- Reporting and coordination.

This protocol will be suitable for initial implementation by the Air Force. However, it should not be considered fixed and unchanging. No sampling protocol is fixed forever. The sampling and analytical procedures should be subjected to both continuing and periodic review for feasibility of sampling techniques, appropriateness of data, frequency of sampling and its relationships to other activities (such as remedial actions).

3.10.4 Conclusions

For the sampling protocol task, Radian has developed a sampling strategy and initiated development of a sampling protocol for the ongoing

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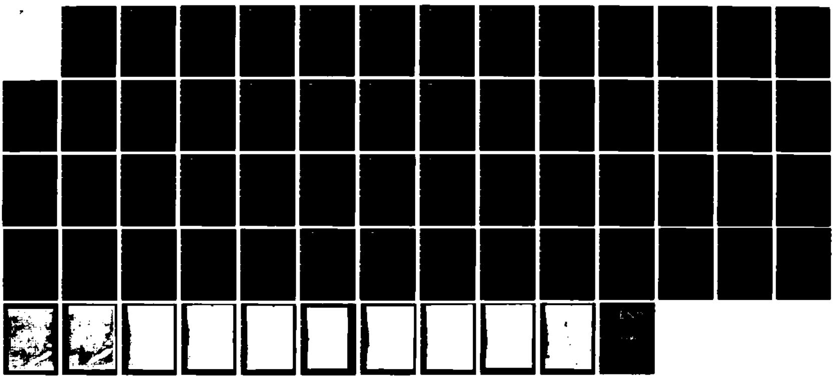

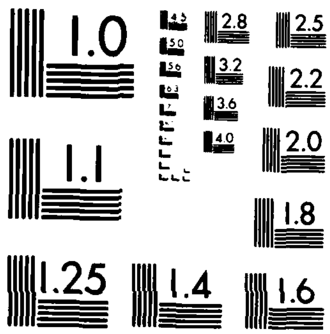

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McClellan AFB ground-water monitoring program. The major elements of the sampling strategy are:

- The monitoring network will consist of 100 wells: 50 on-base, 50 off-base.
- Chemical analyses will be conducted by EPA Method 601, with second column confirmation as back up.
- The complete protocol will be developed in the next stage of the project.

3.11 Task 11 - Hydrogeologic System Evaluation

For Task 11, Radian evaluated the hydrogeologic system of the McClellan AFB area. This task was conducted after the completion of the reconnaissance boring effort.

3.11.1 Objectives

The main objective of Task 11 was to evaluate the hydrogeologic system in the McClellan AFB area as a guide to potential ground-water modeling efforts. Additional data required to evaluate the hydrogeologic system in the area of the base were also to be identified. Based on the results of the hydrogeologic system evaluation, a ground-water modeling strategy for the McClellan AFB area was to be designed (Task 12).

3.11.2 Approach

The first effort of the Hydrogeologic System Evaluation Task was a review of both the literature and the data developed by Task 2, Data Review. The results of Task 3, Reconnaissance Borings, were also reviewed. From the literature and data review, the hydrogeologic system of McClellan AFB was evaluated from the standpoint of ground-water modeling. A suggested ground-water modeling strategy was developed in Task 12 based on the system evaluation. Additional data requirements were also identified. The results and findings of the system evaluation are discussed below.

3.11.3 Results

Hydrogeological System of the McClellan AFB Area

Saturated strata, from the water table to moderate depth, consist of the Laguna and Fair Oaks Formations and, in deeper zones, the Mehrten Formation. These formations are fluvial deposits containing interbedded sands, silts, and clays. Gravel is occasionally encountered in major stream-channel

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deposits. As discussed in Section 3.5, ground water in the study area occurs at shallow depths (80-100 feet), primarily under unconfined conditions. Locally, confined and partially confined conditions exist with depth where confining strata are encountered. Also, intermittent perched zones are encountered seasonally at a local scale.

Based on the results of the reconnaissance borings and review of existing information, strata in the area of McClellan AFB vary considerably both horizontally and vertically. Individual layers of sediments are highly discontinuous. Little if any correlation of stratigraphic units is possible, even within short distances. Correspondingly, the hydraulic and attenuative properties of the strata also vary significantly within short distances. No distinct, laterally continuous aquifers were identified in this investigation. The shallow and deep aquifers described by a previous investigator (Engineering-Science, 1983) apparently do not constitute distinct separate aquifers.

Locally, hydraulic differentiation between water-bearing zones may occur where exogenous factors such as pumping or infiltration induce a vertical component to ground-water flow. At a regional or sub-regional scale, sufficient hydraulic interconnection between water-bearing zones probably occurs such that the zones should not be considered as distinct aquifers but as integral parts of a regional aquifer system. Ground-water contaminants confined to shallow water-bearing strata near waste disposal areas will spread to deeper, hydraulically connected water-bearing strata as they are transported by regional horizontal flow. Vertical spreading of contaminants will result in part from macro- and micro-dispersion processes. Vertical flow components noted during this and previous investigations (CH2M Hill, 1984d) may also facilitate the downward migration of ground-water contaminants.

Accurate prediction of hydraulic and mass-transport processes in highly variable fluvial deposits, such as those encountered in the area of

McClellan AFB is usually difficult. Ground-water flow regimes and mass-transport processes can be highly complex on a local scale, where the properties of the geologic media vary greatly. The location and orientation of paleochannels within fluvial deposits can greatly affect the movement of solutes in ground water, as demonstrated by Osiensky et al., 1984.

The problem of predicting the movement of contamination in a highly variable system, such as that of the McClellan AFB area, is one of scale. Where the evaluation is to be conducted at a local scale, the investigator should account for spacial variability in the geometry and hydraulic properties of the strata in order to develop a proper representation of the system. However, only the overall or average characteristics of an aquifer system become important at a regional or sub-regional scale.

Additional Data Requirements

Additional data on hydrogeologic conditions in the area of McClellan AFB are required for determining the nature and extent of ground-water contamination in the area of the base. As discussed in Section 3.3, a plot of wells known to have been impacted by industrial organic compounds was developed (Plate 4) for the base and surrounding areas. From this plot, general areas of ground-water contamination can be identified. Water-quality analyses utilized to develop the plot were derived from well sampling programs conducted by state and local agencies in association with the Air Force. Based on well construction information and sampling procedures, these analysis should be considered as representing at-the-tap water quality, not necessarily reflecting actual ground-water conditions. A dedicated off-base monitoring well network should be established to provide more detailed information on the nature and distribution of ground-water contamination in the McClellan AFB area.

The design of an off-base monitoring well network is developed in Section 3.13. Suggested monitor well construction practices are detailed in Section 3.7.

Additional data are required for characterization of local hydraulic conditions in the area of McClellan AFB. Aquifer performance evaluations (pump tests) are essentially limited to those performed in recent studies (Engineering-Science, 1983 and CH2M Hill, 1984b) for off-base areas. Data on aquifer parameters are required for local off-base areas so that ground-water flow and contaminant movement can be properly evaluated. Additional information on the hydraulic properties of the strata are also required for possible future remedial actions. Suggested aquifer testing efforts are discussed in Section 3.6.

As the result of Task 2, subregional hydrogeologic information has been collected and assimilated into appropriate file sets and databases. This information appears, for now, to adequately define subregional conditions.

3.11.4 Conclusions

The shallow ground-water system in the area of McClellan AFB is extremely heterogeneous. That is, strata within the system vary greatly both horizontally and vertically. Prediction of the movement of contaminants within this system on a local scale will require extensive data collection. The evaluation of contaminant movement on a larger or sub-regional scale will require that the properties of representative sub-units or areas of the aquifer system be characterized. At regional or sub-regional scale, the aquifer system appears to be consistent.

Additional data are required for determining hydrogeological conditions in the local area of the base. Data for off-base areas are needed to assess present conditions and future movement of ground-water contaminants. An intensive field investigation is suggested to supplement available data for the characterization of local ground-water contamination and hydraulic properties. The designs for the various field investigations are presented in Sections 3.6, 3.7, 3.10, and 3.13 of this report.

3.12 MODEL SELECTION/ACQUISITION

Task 12-Model Selection/Acquisition was one of the final tasks to be conducted as part of Phase II, Stage 2-1 of the McClellan Air Force Base (AFB) Installation Restoration Program (IRP). This task was performed near the completion of the study so that all available information pertaining to the hydrogeologic system could be considered for the selection of an appropriate modeling methodology.

3.12.1 Objectives

The main objective of the model selection/acquisition effort was the identification of a model or modeling code which, as accurately as possible, will predict the movement of ground-water contaminants originating from sources at McClellan AFB. The selection process was to consider the following criteria for the evaluation of candidate models:

- Universal acceptability;
- State-of-the-art methodology;
- Digital equipment requirements;
- Capacity for producing accurate simulations; and
- Portability between computer systems.

Numerical model pre- and post-processors were also to be considered with respect to their ability to economize the modeling process. Selected model(s) were to be purchased by Radian, if not already owned by the company.

During the model selection effort, it became apparent that an overall design for possible future modeling efforts was needed at this juncture. Thus, another objective assumed for this task was the design of future modeling efforts.

3.12.2 Approach

The first effort conducted for the model selection/acquisition task was a comprehensive review of available data pertaining to the hydrogeologic setting of McClellan AFB and surrounding areas. The review included consideration of the literature, numerous geologic logs of on- and off-base wells/borings, and the findings of the off-base reconnaissance boring effort conducted by Radian. The approach and findings of the hydrogeologic setting review are described in Section 3.11.

A literature review was conducted to evaluate the present availability and capabilities of ground-water modeling methods. The literature review included consideration of the following publications:

- Geohydrochemical Models for Solute Migration, Volume 1: Process Description and Computer Code Selection, Battelle, Pacific Northwest Laboratories, (Kincaid, et al., 1984);

- Holcombe Institute, International Ground Water Modeling Center (IGWMC) Selected Summary List of Ground Water Models Which are Documented and Available, IGWMC MARS Data Base, (IGWMC, 1982); and

- Ground-Water Management: The Use of Numerical Models, Water Resources Monograph 5, American Geophysical Union, (Bachmat, et al., 1980).

Radian's professional judgement and experience in ground-water modeling was also employed in the model selection and evaluation process. In addition, Radian project members met with technical representatives of the Hydrotec Division of Williamson and Schmidt (a California-based consulting firm) on several occasions to discuss modeling strategies and candidate models.

Based on the review of the hydrogeologic setting of McClellan AFB and model specifications, a modeling strategy was developed and candidate ground-water modeling codes were selected. General data requirements for the modeling efforts were also identified. Suggested modeling efforts and candidate codes are discussed in the following section.

3.12.3 Results

A suggested methodology for ground-water modeling has been developed. The following sections describe the methodology and its objectives. Candidate numerical modeling codes, data pre- and post-processors and general data requirements are also described. A general discussion of ground-water models/modeling has been included as background in Appendix 12-A.

3.12.3.1 Modeling Objectives

Based on Radian's present knowledge of the shallow aquifer system in the area of McClellan AFB and the present nature and distribution of ground-water contaminants originating from on-base sources, it is recommended that future ground-water modeling efforts be performed based on two main objectives. One objective of the modeling effort should be to define the probable impact of migrating organic contaminants on off-base receptor points at a sub-regional scale. The other objective of the modeling effort should be to develop a means of predicting the impact of potential mitigation measures for contaminant plumes which originate from on-base sources. A localized modeling effort will be required for developing or evaluating strategies for ground-water remediation. The methodology for ground-water modeling is detailed in the following section, along with descriptions of selected ground-water modeling codes.

3.12.3.2 Suggested Modeling Methodology

A staged approach has been designed for ground-water modeling studies for McClellan AFB. The first stage or activity to be conducted, Activity One, is the development/modification of the conceptual model of the hydrogeologic system for the area of McClellan AFB. The second activity consists of sub-regional modeling, followed by local-area modeling as Activity Three. The various activities of the suggested modeling effort are depicted in Figure 3.12-1 and are discussed below. Candidate numerical modeling codes have been selected for Activities Two and Three. A discussion on data pre- and post-processors has also been included.

Activity One - Development/Modification of the Conceptual Model

Modeling efforts should begin first with the development of a more complete conceptual model of the sub-regional and local hydrogeologic system(s) in the area of McClellan AFB. A preliminary conceptual model of hydrogeologic conditions in the area of McClellan AFB was developed from previous regional and on-base investigations, and from off-base studies conducted by the CRWQB, CVR, County of Sacramento and Radian Corporation. The current conceptual model (hydrogeologic characterization) is discussed in Section 3.5.

As discussed in Section 3.11, additional data are required for determining hydrogeologic conditions in the area of McClellan AFB. Present water-quality data for off-base receptor points should, for the most part, be regarded as at-the-tap water quality and not representative of aquifer conditions. A dedicated, zone-specific, monitoring network should be established for providing reliable data on water-quality and hydraulic conditions in the shallow aquifer system around McClellan AFB. The establishment of a dedicated off-base monitoring well network is proposed for Stage 3.

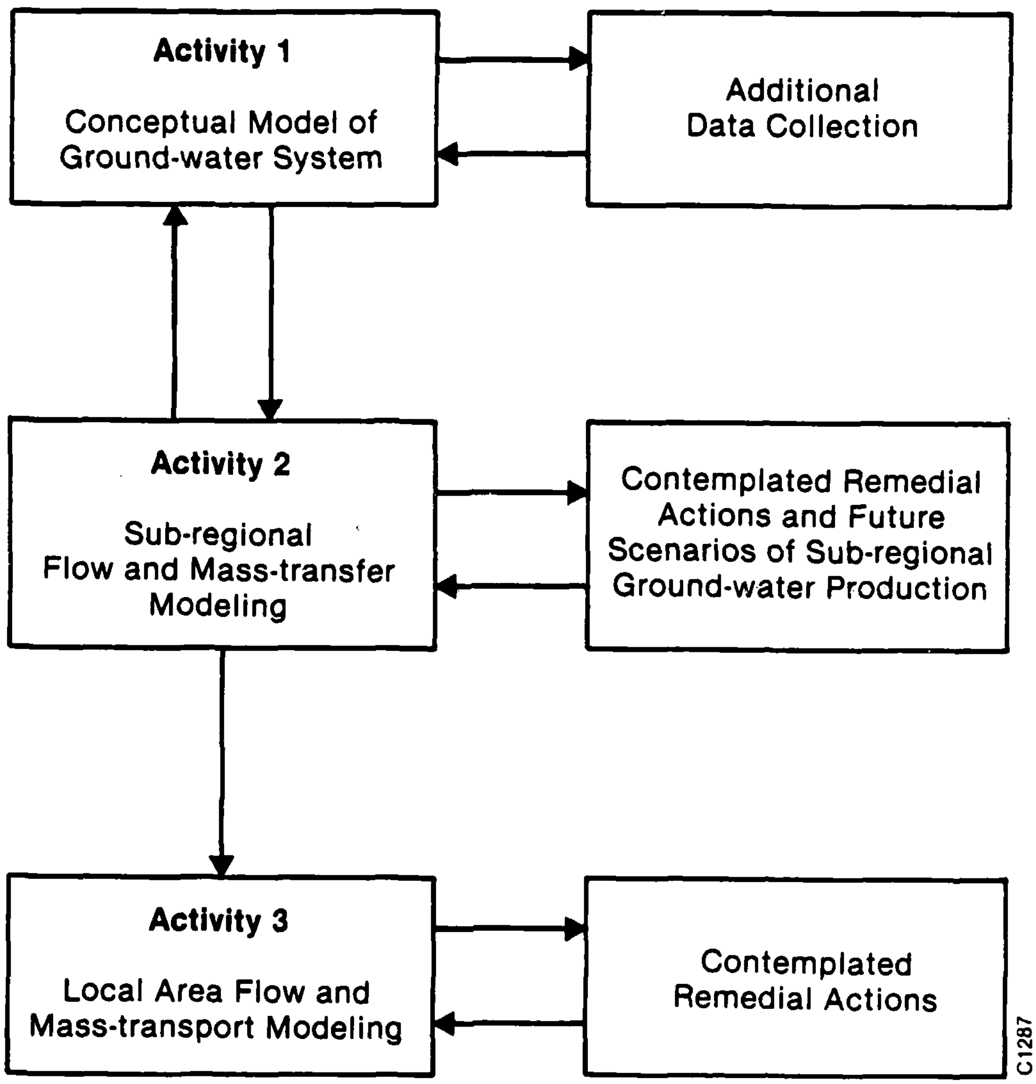

Figure 3.12-1. Flow Chart of Proposed Ground-Water Modeling Approach

Following the completion of the off-base monitoring well network installation and testing effort, the conceptual model of the shallow ground-water system in the area of McClellan AFB should be modified as required.

Activity Two Sub-Regional Ground-Water Modeling

Two aspects of the possible future sub-regional ground-water modeling efforts were considered by this study. The first was the selection/acquisition of a suitable ground-water "model" or modeling code. The second was the development of the general methodology for sub-regional ground-water modeling. The results of these efforts are discussed below.

Model Selection/Acquisition

Based on the updated conceptual model of the hydrogeologic system, a sub-regional ground-water model should be established. Given the present knowledge of the hydrogeologic system in the area of McClellan AFB, sub-regional modeling should be conducted with the use of a numerical code. The numerical code should be capable of simulating transient and steady-state flow and mass transport in a single-phase, single-density, non-homogeneous, two-dimensional water-table system with accretion. A three-dimensional code may be required if, based on the results of additional off-base field investigations, the shallow aquifer system is found to contain distinct water-bearing zones or aquifers on a sub-regional scale.

Final selection of a suitable numerical code for sub-regional modeling will be contingent upon the conceptual model developed for on- and off-base areas. Because additional data collection efforts are required for the development of the final conceptual model, final selection of a numerical code for sub-regional modeling is not possible at this juncture. Nevertheless, suitable numerical modeling codes were selected as generally meeting

the criteria listed in Section 3.12.1. These codes are TRANS (Prickett, et al., 1981) and USGS-MOC (Konikow and Bredehoeft, 1978). Detailed descriptions of TRANS and USGS-MOC have been included in Appendices 12-B and 12-C.

TRANS and USGS-MOC employ modern numerical methods capable of producing accurate mass transport simulations. Each has attained a reasonable measure of acceptance among ground-water modeling professionals. As evidenced by Kincaid et al. (1983), both models appear to be suitable for subregional modeling. However, given the present conceptual model of the hydrogeologic system in the area of McClellan AFB, each has distinct advantages and disadvantages.

TRANS is capable of simulating non-conservative transport and USGS-MOC is not. Depending on the compounds to be considered in the mass-modeling effort, non-conservative transport may be an important factor in modeling the spacial and temporal distribution of sources. Based on distribution coefficients presented for chlorinated hydrocarbons by Lyman et al. (1982), trichloroethylene and similar compounds appear to be fairly conservative in media such as that encountered at McClellan AFB. However, it is assumed that non-conservative transport processes in the form of solute-geologic matrix reactions will be an important consideration for predicting the movement of ground-water contaminants in the area of McClellan AFB. Thus, TRANS is more likely the better suited algorithm for the McClellan AFB modeling effort.

Another possible advantage of TRANS over USGS-MOC is that TRANS is capable of accounting for temporal variability in saturated thickness where USGS-MOC is not. This may be an important consideration where the saturated thickness of the aquifer system changes significantly with time.

Both TRANS and USGS-MOC account for anisotropy in an aquifer system. Depending on the system to be modeled, anisotropy may be an important consideration. Neither TRANS nor USGS-MOC directly account for gaseous-phase or biodegradational losses of contaminants. Many of the

organic ground-water contaminants in the area of McClellan AFB are volatile. Additionally, experiments such as those conducted by Parsons et al., 1984, indicate that certain organic species, such as those encountered at McClellan AFB, may be subject to biodegradation. The use of a modeling code which does not account for these processes may bias model predictions towards overestimating contaminant transport rates.

Both TRANS and USGS-MOC are reasonably portable between computer systems. Both codes are written in FORTRAN IV (formula translation language), a widely used language for scientific/engineering applications.

Compiled versions of TRANS and USGS-MOC (updated as of October, 1983) have been acquired by Radian Corporation for execution on a UNIVAC 1100 Series mainframe computer system. Depending on the type of system utilized, modifications in the modeling code may be required for implementing the code(s) on systems with device labels differing from those addressed in the source code.

Modifications may also be required where the FORTRAN version used by the source code differs from that of the employed compiler. Modifications can be required where the available memory of the computer system on which the model is to be implemented is less then that of the machine used to develop the source code. Memory restrictions may require that "comment" statements be removed from the code or that the vector/array dimensions be sized down. In the case of the sized-down vector/array dimensions, the simulation capability of the numerical code may be reduced.

General Methodology for Sub-Regional Flow Modeling

The sub-regional numerical flow model should be constructed to incorporate all significant features of the shallow ground-water system which control sub-regional flow to potential receptor points. Given the present conceptual model of the hydrogeologic system in the area of McClellan AFB,

the area to be considered by the sub-regional model is likely to include the entire area of McClellan AFB, areas west of the installation which are subject to receiving contaminants from the base and areas of municipal production to the south and east of the base. The actual area to be considered by the model will be based on the water-level measurement and interpretation efforts planned for the next stage of Phase II.

Lateral boundaries for the sub-regional model will be established at appropriate hydraulic boundaries or where the boundaries produce limited influence on modeled areas under closest consideration. Lateral boundary conditions for the sub-regional model will most likely be boundaries of prescribed potential (first-order boundary condition).

Specifications for aquifer parameters and hydraulic stimuli should be developed from the conceptual model of the hydrogeologic system. System parameters such as hydraulic conductivity and pumpage will require estimation where data are not readily available. Estimates for the hydraulic parameters should be developed from information provided by previous investigators, the literature, productivity or specific capacity tests for area wells, and the results of the planned aquifer testing program. Aquifer parameters for areas not directly measured may be interpolated/extrapolated using a least-squares interpolation approach or appropriate statistical method, in association with professional judgement.

Input data interpolation may be suitably performed using Radian's Contour Plotting System (CPS™) software, or a similar contouring package employing the linear least-squares interpolation method. Data pre-processing can also be achieved using statistical package software.

Calibration efforts for the sub-regional flow model should consist of testing the model's response to known exogenic factors and comparing water level outputs against historical water level data, where such data are available. Calibration efforts will require historical data on water levels,

pumping (from public and private wells) and recharge (natural and man-made). If, during the calibration process the model does not respond to a known set of stimuli so as to mimic historic conditions, the conceptualized model of the system may require modification. The calibration process may provide a means by which to verify or modify basic conclusions formed for the hydrogeologic system of study.

Flow calibration efforts should be considered complete when reasonable adjustments to the system representation produce accurate hydraulic simulations. Calibration of the model may not be reasonably achieved due to unknown or unaccountable characteristics of the shallow aquifer system and/or limitations of historical data. If calibration efforts are not successful, subsequent mass-transport modeling may require the use of a steady-state flow model.

If model calibration efforts are successful, simulation of future hydraulic conditions in the area of the installation should be possible. Estimates of future pumping and recharge in the area are required for performing predictive hydraulic modeling. Predictive hydraulic modeling may be performed for the evaluation of hypothetical cases such as the hydraulic effect of the curtailment of local ground-water production by area private and/or municipal wells.

The main objective for the development of a sub-regional flow model is to provide a basis for sub-regional, transient, contaminant-transport modeling. Contaminant transport modeling may be performed if a dynamic flow model cannot be developed through calibration. Such an effort would require that mass-transport modeling be performed for conceptualized or hypothetical steady-state flow fields. In either case, values for the dispersivity of the shallow aquifer system will be required. Values for the lateral and longitudinal dispersivity of the aquifer system can probably be approximated from field data.

Mass-transport modeling will require that source concentration terms be quantified. A relatively large number of organic compounds exist in the shallow ground-water system as the result of past base operations. Mass-transport modeling efforts will probably be confined to predicting the movement of one or two representative species of concern. Source-term concentrations for the parameters of interest should be estimated from concentrations noted in the ground water in the immediate vicinity of the source areas.

Contaminants traveling through the ground-water system in the area of McClellan AFB may be subject to adsorption-desorption processes in addition to possible chemical and biological degradation. Modeling efforts for species of concern should account for the possible chemical interaction of the contaminants within the geologic matrix. The distribution coefficient for the species of interest may be estimated from values developed in the literature. Conservative mass transport may also be assumed by the modeling effort. The assumption of conservative mass transport will bias modeling results in favor of overpredicting contaminant movement.

Sub-regional mass transport modeling efforts will require that the mass transport model be calibrated against existing data. Calibration will consist of the adjustment of transport parameters such that the model will suitably predict historic/present conditions. Data required for the calibration of the transport model include dates of waste disposal at the base and representative water-quality analysis for off-base areas.

After the mass-transport model has been calibrated, predictive simulations can be performed. Such simulations would probably include various scenarios of sub-regional ground water production, as considered in the hydraulic modeling effort. The sub-regional effect of potential remedial actions may also be evaluated.

Activity Three - Local-Area Modeling

As the result of previous investigations, four general areas of past waste disposal operations have been identified. Efforts to be conducted as part of the next stage of Phase II will include the location and characterization of contaminant plumes emanating from on-base sources. Depending on the type of remedial strategy adopted (if any), local-area contaminant transport modeling may be justified for the evaluation of remedial action alternatives.

Two aspects of possible local-area modeling efforts were considered in the study. The first was the selection of candidate modeling codes. The second was the development of the general methodology for local-area modeling. The results of these efforts are described below.

Model Selection

Local-area contaminant transport modeling will probably consist of establishing separate models or representations for each plume area. The use of a three-dimensional, transient, mass-transport algorithm will probably be required for the local-area modeling effort.

Local conditions in the area of McClellan AFB have not yet been completely characterized. The design of the local area models and type of modeling code required will be contingent upon local conditions and the remedial alternatives to be evaluated. Nevertheless, an algorithm will probably be selected from programs such as those developed by Trescott (1975) or Durbin and Berenbrock (1984). These numerical ground-water modeling codes have been tentatively identified as being capable of producing

accurate simulations using modern numerical methods, having attained a reasonable degree of acceptance among ground-water modeling professionals and being reasonably portable between computer systems. Because the selection of the local-area modeling codes at this juncture is only tentative, no further discussion of the identified codes has been included.

General Methodology for Local-Area Modeling

The overall methodology of the local contaminant transport modeling effort should probably begin with the development of a three-dimensional representation or grid of the areas to be modeled. The area to be incorporated into each local area model should include the contaminant source, the area which is directly affected by ground-water contamination and local hydraulic features of consequence, such as wells.

The physical properties of the aquifer for the local-area modeling effort will be provided by the results of the field investigations and the findings of the sub-regional modeling effort. Data pre-processing efforts, such as those described for the sub-regional modeling effort may be employed for local-area modeling. Contaminant attenuation parameters will probably be derived from the literature and/or results of the sub-regional modeling effort.

Calibration efforts for local area models will be essentially the same as those employed for the sub-regional modeling effort. Following calibration, the various local-area models can be used for the evaluation of remedial strategies. Various scenarios of pumping and plume control can be evaluated. The models may also be used for optimization of recovery and injection wells and design/optimization of ground-water treatment plants and supporting distribution systems.

Model Post-processors

Numerical results from the various modeling efforts will probably require graphical representation for interpretive analysis. A contour plotting system, such as Radian's CPS or equivalent, should be employed for the reduction of numerical data to graphical form. Transfer of model output data to a plotting package should be performed automatically using an interface program developed for the modeling effort. The use of an interface program will minimize possible data transfer errors and reduce labor requirements for successive modeling efforts.

3.12.4 Conclusions

Based on a review of the hydrogeologic setting of McClellan AFB and available modeling technologies, a staged methodology for ground-water modeling for the McClellan AFB area is recommended. The recommended stages are:

Activity One - Development/modification of the conceptual model of the ground-water system.

Activity Two - Sub-regional modeling.

Activity Three - Local-area modeling.

Given the present understanding of the hydrogeologic system in the area of McClellan AFB, general methodologies for ground-water modeling were developed. Numerical codes were tentatively identified for Activities Two and Three. TRANS and USGS-MOC were acquired for Activity Two. Final model selection for Activities Two and Three was not possible at this juncture due to data limitations.

Efforts for the next stage of the McClellan AFB IRP should include the refinement of the present conceptual model of the hydrogeologic system

and the final selection and implementation of a sub-regional flow model. Efforts for follow-up studies should include sub-regional and local-area mass-transport modeling.

The use of numeric ground-water models for the evaluation of the McClellan AFB ground-water contamination problem appears to be justifiable. The success and results of the numerical modeling effort for the McClellan AFB investigation cannot be exactly determined until model implementation has been performed. Thus, data collection and analysis activities for subsequent tasks should not be solely supportive of possible future modeling efforts but should also support analysis by conceptual and/or analytical means.

3.13 Task 13 - Monitor Well Siting

3.13.1 Objective

The objective of Task 13 - Monitor Well Siting was to select the locations for the proposed monitoring wells to be installed during the next stages of McClellan IRP activities. To date, many monitoring wells have been installed on base. The monitoring wells sited in this task are for the purpose of monitoring ground water in the areas off base.

It has been estimated that approximately 50 monitoring wells will be installed in off-base areas. These wells will be installed in two phases with 30 wells in the first phase and approximately 20 wells in the second phase. Only those wells in the first phase (30) were sited in Task 13.

3.13.2 Approach

Locations for first phase, off-base monitoring wells were selected by the following approach:

- All other tasks (Task 1-12) were completed and the data from the tasks were reduced and analyzed,

- Radian geologists and hydrogeologists involved in the completion of Tasks 1-12 met to discuss future data requirements and well siting priorities, and

- Radian geologists and hydrologists met to select appropriate well locations. All personnel present discussed each proposed location with respect to the data derived from tasks in which they were involved.

3.13.3 Results

The first step toward selection of monitoring well locations, following analysis of Task 1-12 data, was to establish the objectives and priorities of the first stage monitoring wells. The following objectives and priorities were identified:

- The primary priority is to place monitoring wells in areas of known contamination so that contaminant levels could be monitored;

- Well locations should be chosen to more accurately define the lateral and horizontal movement of contaminants;

- In areas where contaminants have been found off-base, yet the origin is unknown, wells should be located along base boundaries in order to identify the contaminant origin; and

- Wells should be located upgradient of the base to determine in flux, if any, of other contaminants.

Utilizing these objectives and priorities, 30 monitoring well locations were selected as shown in Figure 3.13-1. The locations are primarily near the base boundary where contaminants are likely to be higher. Wells to be installed in the second phase may be positioned farther from the base, as necessary.

Table 3.13-1 lists the proposed monitoring wells and the rationale for location selection. Note that the off-base monitoring wells are numbered as 100-series (MW 101, MW 102, etc.) so as not to cause confusion with on-base monitoring wells (MW 1, MW 2, etc.).

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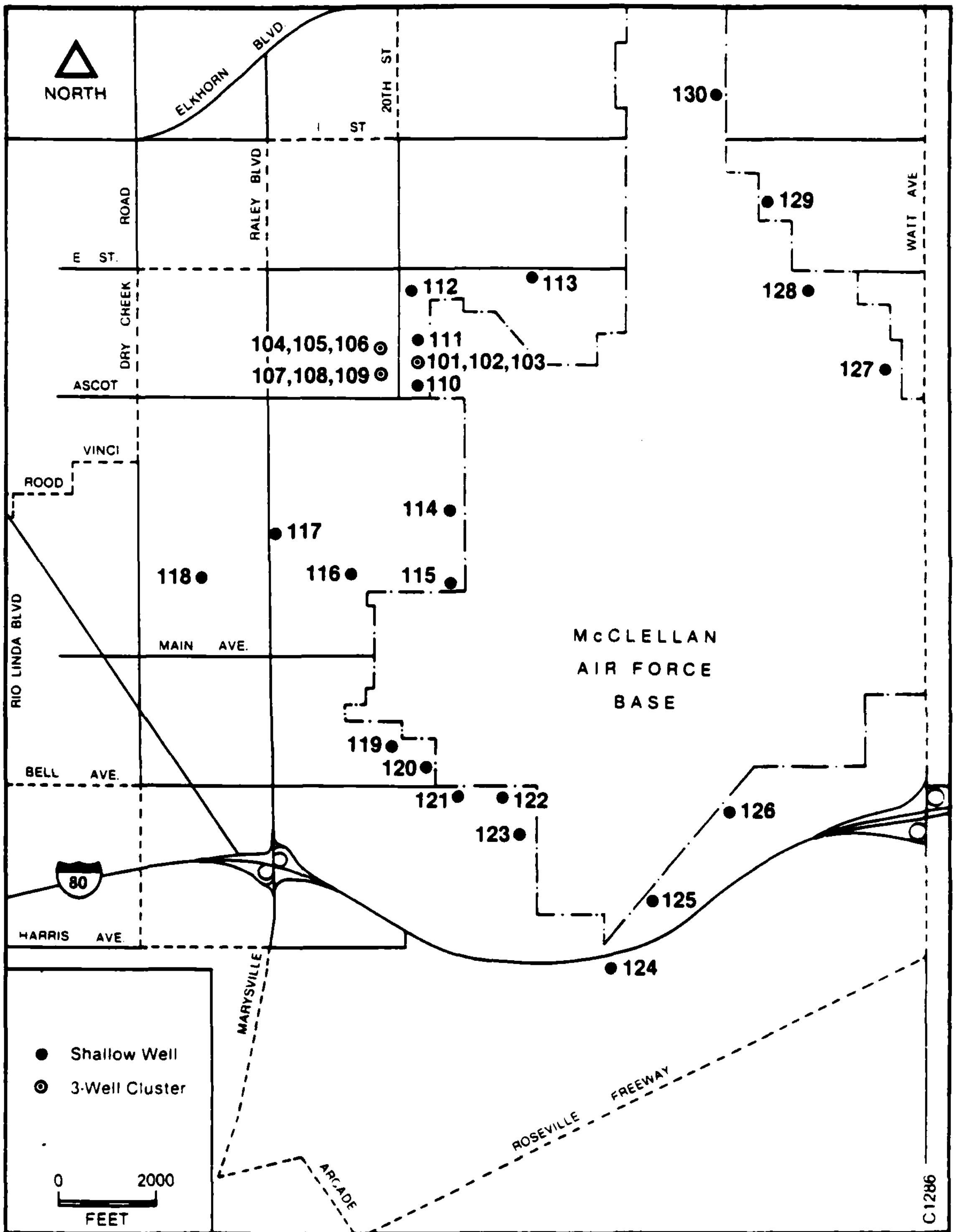

Figure 3.13-1. Location of Proposed Monitoring Wells (First Phase)

TABLE 3.13-1. RATIONALE FOR SELECTION OF MONITORING WELL LOCATIONS
(First Phase Wells)

Well Number	
MW 101 MW 102 MW 103	Well Cluster - Located in area of highest known off-base contaminants. Three monitoring depths to determine the difference between saturated zones at a given point.
MW 104 MW 105 MW 106	Well Cluster - Located to assess 3-dimensional lateral migration from Area D. Three monitoring depths to determine the difference between saturated zones at a given point.
MW 107 MW 108 MW 109	Well Cluster - Third point for determining 3-dimensional lateral migration from Area D. Three monitoring depths to determine difference between saturated zones at a given point.
MW 110	'Shallow' Well - Monitor lateral migration from Area D.
MW 111	'Shallow' Well - Monitor lateral migration from Area D.
MW 112	'Shallow' Well - Monitor area of known impact
MW 113	'Shallow' Well - Monitor area of known impact
MW 114	'Shallow' Well - Monitor ground water near Area C
MW 115	'Shallow' Well - Monitor ground water near Area C
MW 116	'Shallow' Well - Monitor ground water near Magpie Creek
MW 117	'Shallow' Well - Monitor ground water near Magpie Creek
MW 118	'Shallow' Well - Monitor ground water in impacted area near Santa Ana Avenue.
MW 119 MW 120 MW 121 MW 122 MW 123	'Shallow' Wells- Monitor groundwater to determine origin of contaminants southwest of base.
MW 124 MW 125 MW 126	'Shallow' Wells- Monitor ground water between Area A (and other waste sites) and city production wells to the south.

(Continued)

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TABLE 3.13-1. (Continued)

Well Number	
MW 127 MW 128 MW 129 MW 130	'Shallow' Wells - Monitor ground water upgradient of the base to assess what contaminants, if any, are moving toward the base and to serve as background comparison to all other wells.

3.13.4 Conclusions

The first phase of monitoring wells (30 wells) to be installed in the off-base area should be located in an arrangement similar to that shown in Figure 3.13-1 to meet the objectives of ground-water monitoring. These wells will become part of the long-term ground-water monitoring program for the base and, in some cases, may serve as part of a remedial action extraction system.

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4.0 DISCUSSION OF RESULTS AND SIGNIFICANCE OF FINDINGS

Results for the 13 Tasks completed during Phase II-Stage 2-1 activities are discussed within the corresponding Sections 3.1 through 3.13. This section: Discussion of Results and Significance of Findings, summarizes those results and discusses factors which determine the significance of the results.

Task 1 - Project Implementation

The principal result of Task 1 was the establishment of a computer database system to compile and manage the large volumes of data and information collected during Stage 2-1. The database and the associated Project File Sets will prove to be valuable for future environmental work on and around McClellan AFB. Conversion of the database for use by McClellan personnel has been recommended for the next stage of activities.

Task 2 - Data Review

Radian met with Air Force and agency personnel to collect existing data regarding the environmental setting and previous environmental investigations. Information collected was reviewed and applicable data entered into the computer databases as either Site-Specific data (applying to a given point) or General Information (applying to all or part of the study area). Representatives of various water districts in the area and local drilling firms were also contacted for information.

Most data reviewed were assigned confidence levels based upon the reliability of the information. The levels included:

Confirmed:	This information is known to be factual.
Reliable:	This information, while not confirmed, is believed to be correct.

Questionable: This information, for some reason(s), is suspect and should be utilized with caution.

Task 3 - Well Inventory

The well inventory, which is discussed in Section 3.3, identified over 1,000 wells in the off-base area of interest. Data from the two rounds of community contacts were reduced to Site-Specific data and entered into the computer database. The well data can be recalled and listed by x-coordinate, y-coordinate, grid cells, well status, or other parameters. The database should prove valuable in future work elements in identifying wells in areas of concern, identifying possible sampling points, and tracking contaminant migration.

Approximately 62% of all residences in the area of interest responded in the well inventory. It is believed that many of the 38% unaccounted for do not have wells and, therefore, did not return the mail-in form, even though return was requested. Also, many forms mailed out during the second round of the survey were returned as undeliverable, due primarily to vacant residences. Therefore, although a high percentage of wells in the area have been identified, there are probably more wells to be added. It is recommended that the database be continually expanded and maintained as new well information becomes available.

Task 4 - Geological Investigation Planning

The Geologic Investigation Planning task selected a drilling method to be used during exploratory drilling and the locations of the borings to be drilled. Dual-tube air-rotary drilling was selected because it is relatively fast, allows identification of saturated zones, provides good formation "cuttings" return to ensure accurate geologic logging, and provides a means to obtain water samples representative of aquifer conditions. Although compressed air is the primary agent* utilized to

*Small volumes of water were used occasionally to aid in penetrating hard formations and in lifting cuttings.

circulate cuttings to the surface during drilling, the air is circulated mainly internally, not through the bit into the formation. Therefore, water coming into the drill stem when air circulation has been stopped, has not been significantly impacted by air-stripping of volatiles.

Task 4 activities included the selection of drilling locations for the reconnaissance borings. Twenty locations were selected (contract limit) and were presented to Air Force and agency personnel. The agencies recommended nine additional borings be drilled and that all borings be extended to a depth of 200 feet. These recommendations were incorporated into the proram although a five week delay for contract modification resulted.

Task 5 - Reconnaissance Borings

Twenty-nine reconnaissance borings were drilled to approximately 200 feet below land surface (BLS). During drilling, formation samples were retained and composited at five-foot intervals. In saturated zones, formation samples were retained and analyzed for grain-size distribution. Both the geologic logging of the borings and the results of the grain-size analyses indicated an extremely heterogeneous system, as expected.

Water samples collected from saturated zones were analyzed for pH, temperature, and conductivity on-site and eight inorganic parameters in the laboratory. These tests were conducted to establish general ground-water characteristics and to identify any significant changes in characteristics which would tend to indicate separate and distinct aquifers. Water quality was found to be good; except where contaminants exist, ground water was not highly mineralized. No significant and correlatable changes in parameters were noted. This tends to support the conclusion that the saturated zones are not separate and distinct aquifers.

Water samples were also analyzed for volatile organic compounds by gas chromatography (EPA Method 601). The results of these analyses showed

the presence of organic compounds in ground water to the west of Area D and, to a lesser degree, to the northwest. Organic compounds were not detected immediately southwest of Area D. Organic compounds were detected in groundwater in an area northeast of the base and in lesser concentrations west, southwest, and south of the base. The source of these contaminants is speculative. McClellan AFB is a probable source of contaminants west, southwest, and south of the base. However, there is no evidence to support a conclusion that contaminants seen northeast of the base could have originated from the base. Therefore, contaminants northeast of the base probably originated from another source. This conclusion is supported by groundwater flow patterns determined from water-level elevations measured in early September 1984. These showed ground water in both the shallow zones (less than 120 ft. deep) and deeper zones moving generally from northeast to southwest. However, the flow apparently splits in the northern portion of the base, probably as a result of the influence of extensive pumping northwest of the base. Consequently, there is a component of flow that moves west and northwest in the vicinity of Area D in addition to the main northeast-southwest flow.

It should be noted that the water level elevation contours shown on Plates 7 and 8 are for a single measurement period and only for wells on base. In order to more accurately define the hydrologic system, it will be necessary to repeat the measurements during other times of the year, and to expand the water level measurements to off-base points, when available.

It should also be noted that the steep gradients and sharp contour deviations seen on some parts of Plates 7 and 8 are probably not representative of the real ground-water system. These may be the result of erroneous water level values which may be caused by poor well construction and/or by the extrapolation routines of the computer. However, it is believed that the general patterns of flow are reasonably accurately represented, as evidenced by the similarity between maps for the shallow and deep zones.

Utilizing the computer-generated plots for ground-water elevations (Plates 7 and 8), a head difference map (Plate 9) was created by subtracting the head elevations on Plate 8 from those on Plate 7. This head difference indicates the potential for flow between the shallow zone and deeper zones. Over most of the base, the positive head difference value indicates a potential for water in shallow zones to move downward into the deeper zone.

Pressures in deeper zones and the shallow zone appear to be approximately equal along the western boundary of the base (along head difference contour line = zero). Where this occurs there is no potential for vertical flow between zones.

The computer has extrapolated the head difference trend to the west as negative values. This exists where deeper zone pressures are greater than shallow zone pressure and, therefore, there is a potential for vertical flow from deep to shallow zones. This is most likely caused by a increase in clays from east to west in the vicinity of the base. The deeper zones are, therefore, more likely to be confined and under artesian pressure. The significance of this is that contaminants moving west from Area D have the potential to move into deeper zones, which may make control and cleanup of contaminants in ground water more difficult.

As noted above for Plates 7 and 8, the data were taken only one time and only on base. The measurements should be repeated, especially during the months of heavier precipitation, and should be expanded to the off base area, when valid measuring points are available.

In general, it is concluded that geologic materials in the vicinity of McClellan AFB are widely variable and are not laterally correlatable over significant distances. Because of this, saturated zones do not appear to occur as distinct and separate aquifers. This was further supported by the lack of distinct differences in water quality.

Although natural water quality is good, ground water has been impacted by contaminants near Area D. Sources of contaminants in other areas are not known, but available data suggest they are probably located on McClellan AFB. One important exception is contaminants located northeast of the base. Because this area is located upgradient of any known sources on base, contaminants are probably from a source other than the base.

Task 6 - Aquifer Test Planning

Plans for aquifer testing were developed in Task 6. It was determined that a comprehensive aquifer test including the ability to induce a cone of depression would be necessary to determine aquifer parameters and the interconnection of saturated zones. To accomplish this, a location west of the base was selected for testing, provided property access can be obtained. This location is close to Area D but in an area apparently free from significant contamination at this time.

Two pumping wells and three piezometer clusters are recommended. Two independent pump test will be conducted using all 11 measuring points to determine time versus drawdown curves.

It was also recommended that single-well pump or slug tests would be conducted in each off base monitoring well to be installed during future activities. This will provide supporting aquifer data for all areas around the base.

Task 7 - Selection of Well Construction Technology

Task 7 activities included a review of information regarding drilling methods used in the area and the requirements for future monitoring well installations. It was determined that large diameter, hollow-stem auger drilling would be the preferred drilling method for wells up to 120 feet deep. For deeper monitoring wells, air rotary drilling with casing

drive is the preferred method. Both of these methods allow accurate identification of saturated zones.

Task 8 - Sampling Materials Study

Task 8 activities included a review of existing literature regarding material compatibility for monitoring wells and sampling equipment, and selection of the most appropriate materials. It was determined that monitoring wells should be constructed with stainless steel well screens and casing blanks through the wetted length of the well. Polyvinyl chloride (PVC) may be utilized as well casing above the static water level.

Sampling equipment should be limited to stainless steel and Teflon materials, including the pump and discharge lines.

Task 9 - Sample Equipment Design

Various ground-water sampling systems were assessed to determine which system was most cost-effective while providing valid samples. Costs were compiled for both a dedicated system (pumps installed in each well) and a portable system (pump unit moved from well to well).

It was determined that a combination of the two systems offered the most cost-effective alternative. For all monitoring wells completed in the uppermost aquifer, a portable system is most cost-effective. For deeper wells, where a large volume of water must be purged from the well before sampling, a dedicated pump with a packer above the screen will be most efficient.

For the portable unit, a reciprocating piston pump system is recommended. Dedicated pumps installed in deeper wells may be either reciprocating piston pumps or air-driven bladder pumps.

It should be noted that the selection of a portable sampling

system, for most of the monitoring wells is less expensive but requires greater labor and time. Although these factors were considered in the detailed costing, the Air Force may choose to select the less labor-intensive sampling system if personnel are unavailable.

Task 10 - Sampling Protocol

A sampling and analysis scenario was developed in Task 10. A detailed sampling protocol will be developed in future activities, once the sampling system has been chosen.

It was assumed that the monitoring well network would be composed of 50 on base and 50 off base wells. This system would initially be sampled quarterly. With time it is anticipated that wells consistently not showing contaminants could be dropped from quarterly sampling to annual or semi-annual sampling.

Sample analysis should be conducted for volatile organic compounds by EPA Method 601. In addition, a second sample should be retained for analysis by gas chromatography - mass spectroscopy (EPA 624/625) if needed. Therefore, if the EPA 601 analysis requires species confirmation or if non-601 species are suspected, the GC/MS analysis may be conducted.

Task 11 - Hydrologic System Evaluation

Data regarding the hydrologic system in the vicinity of McClellan AFB was reviewed with respect to usefulness of the data in future modeling efforts. It was determined that relatively little information was known about aquifer parameters, flow, and quality in the off base area. In order to conduct flow modeling (advection modeling) it will be necessary to first determine aquifer parameters, especially leakage between zones, and to determine water levels in the off base area. Mass-transport (solute transport) modeling will require sampling and analysis of monitoring wells in the

off base area and this sampling must encompass both horizontal and vertical controls in order to assess the potential for three-dimensional transport.

Task 12 - Model Selection/Acquisition

Various modeling packages were reviewed to determine which models were most appropriate for future modeling activities. These modeling activities have been divided into two principal efforts: flow modeling and mass transport modeling.

For the flow modeling effort, the models known as TRANS and USGS-MOC have been selected as being most suitable. Radian has acquired both of these modeling codes. No mass-transport model has been selected because it will be necessary to evaluate the results and validity of the flow model first. Because only a few mass-transport models currently exist, the selection of a mass-transport model will be a minimal effort.

Task 13 - Monitor Well Siting

Monitoring wells to be installed off base in future activities will be installed in two phases. The first phase is estimated to include 30 wells and the second phase will include 20 wells. In Task 13 Radian selected the locations for the first phase of monitoring well installation. The locations were selected to emphasize areas of known contamination or where the contaminant source is in question. For these reasons, the first phase of monitoring wells are predominantly located near the base. It is anticipated that the second phase of monitoring well installations will be used to "fill-in" data gaps in areas of suspected contamination or extend the information beyond contamination identified in the first phase wells.

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5.0 RECOMMENDATIONS

Recommendations for work to be accomplished in Phase II-Stage 2-2 at McClellan AFB are discussed in the following paragraphs.

- Database Conversion

As part of Delivery Order 16 activities, Radian reviewed existing information regarding the environmental setting and other information relating to contamination at McClellan AFB. This information was reduced and placed in a database using an IBM Personal Computer XT (Model 5160) with 512K memory operating under the PCDOS version 2.10 operating system. The database management system software used was Knowledgemanager by Micro Data Base Systems, Inc. In addition, results of the well inventory task and reconnaissance boring task were reduced and placed in a database. It is estimated that approximately 2 megabytes (MB), or roughly 2 million characters of data will be stored in these databases at the conclusion of Stage 2-1 activities.

In order to provide base personnel with permanent and timely access to and management of the databases mentioned above, the following options are offered: 1) procurement of a system (hardware, operating system, and database management software) by the Air Force which is compatible at the hardware, operating system, and data base management software levels with Radian's system (as detailed in the preceding paragraph); 2) procurement of the hardware and software, or third party service, necessary to convert the data files derived from the Radian databases into a form compatible with input requirements of the Air Force system given that such system is incompatible with Radian's. These two options are discussed below.

Option 1.

The preferable option from labor minimization, data integrity, data security, data management and maintenance perspectives will be to transmit the updated databases via modem from Radian to a base computer system (hardware, operating system, database management, and communications software) of compatible configuration. This will allow immediate use of the databases by base personnel, for data management and reporting purposes as the project progresses. The greater the number of interfaces involved in the management of data, the greater the chances are for data loss or corruption. This option requires only one interface - the communications interface between Radian's computer and McClellan's.

Implementation of Option 1 could be achieved by using the Wang Professional Computer with a 10 MB (megabyte) hard disk drive, an asynchronous communications card, MSDOS operating system (version 2.0 or later), Knowledgemanager as the database management software and any communications software supporting the XMODEM communication protocol. Additionally, a modem of the Hayes Smartmodem 1200 type with necessary cabling would be required as communication hardware. Such an implementation would allow a smooth integration (with appropriate software and hardware available from Wang) with the Wang OIS50 word processing system presently being used on base.

Option-2.

This option will convert the databases prepared by Radian into a form usable by the Wang OIS 50 word processing system presently being used on base. This approach requires the following steps (interfaces):

1. Conversion of the Radian databases into standard character (ASCII) data files of an appropriate size for use on the Wang OIS50.

2. These data files must then either:

   a) Be converted to a diskette format capable of being read by the Wang OIS50 operating system (CP/M) and then transmitted on diskettes to the base
   or,

   b) be transmitted via modem to the base Wang OIS50 for storage on diskettes readable by the Wang OIS50.

3. If any data management via data base management system software is desired, the data files thus stored on diskette for use on the Wang OIS50, must be defined for and attached to the database scheme (table definition) following the respective data definition and data input (attachment) requirements of the database management software selected.

Implementation of this option would require the procurement of:

a) Radian services to convert the databases into standard character format (ASCII),

b) Radian services to to transmit data files via modem to the Air Force and hardware (modem) and software (communications) necessary to establish communication between Radian's IBM PC XT computer and the Wang OIS50
   or,

c) Necessary software and Radian services to convert the data files to diskette format capable of being read by the Wang OIS50 and services to transmit the diskettes to the base
   or,

d) Subcontract to third party diskette conversion service for purposes of converting data files as in c) above.

- <u>Aquifer Testing</u>

In order to properly characterize and model the ground-water system in the vicinity of McClellan AFB, and to properly evaluate potential remedial action alternatives, it is necessary to accurately estimate certain aquifer parameters. These parameters; transmissivity, storativity (storage coefficient), leakage coefficient, anisotropy, and other related terms, can only be properly quantified by aquifer testing (sometimes called pump tests).

Two types of aquifer tests are proposed for determining aquifer parameters. The first is a comprehensive, long duration test utilizing pumping and observation wells. This test is discussed in detail later in this section.

The second type of aquifer testing will be short-term pumping or "slug" tests to be performed on monitoring wells as they are installed. This testing is further detailed in Section 2.5, Monitoring Well Installation - First Phase.

The long-term aquifer test was designed based on the results of reconnaissance boring information which indicated that a relatively thin water-table aquifer (unconfined aquifer) exists in most areas around the base, at an average depth of 90-100 ft. below land surface (BLS). This zone probably does not yield significant volumes of water and would not adequately support an aquifer pumping test.

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For the area west of the base, the unconfined aquifer is separated from deeper zones by a sequence of silty-clays with small sand lenses. This sequence probably is not a good confining bed but does provide partial hydraulic separation between zones. From 130-140 ft. BLS, sand lenses form a 'middle' aquifer. These lenses yield significant water volumes but probably do not form a laterally extensive aquifer.

Below the 'middle' aquifer a sandy-clay separates the sand lenses from a more extensive micaceous sand which begins at approximately 160 ft. BLS and continues to depths ranging from 180-200 ft. BLS. This 'deeper' aquifer zone probably has partial hydraulic connection with the above sand lenses.

To properly assess the flow properties of these zones and determine the degree of interconnection between the zones, the aquifer test will utilize two pumping wells and 9 observation wells. The following procedure will be utilized:

- One well will be drilled into the 'middle' aquifer and completed as a pumping well. The actual zone of completion (screen length and depth) will be determined during drilling activities.

- A second well will be drilled into the 'deeper' aquifer and completed as a pumping well. The placement and length of the screened interval will be detemined during drilling activities.

- Three clusters of observation wells will be installed with three individual completions per cluster. In each cluster, wells will be completed in the same two zones as the pumping wells plus the overlying unconfined aquifer.

- o Following completion of all wells, water levels will be monitored for 12 hours prior to initiation of pumping.

- o Pumping will then be initiated in the 'middle' aquifer. Water will be extracted at a constant rate for 48 hours. It is anticipated that the pumping rate will be 50-100 gallons per minute.

- o During pumping, water levels will be monitored in all wells using appropriate measuring equipment and time intervals. In addition, pumping discharge will be measured for discharge rate, temperature, pH, and conductivity.

- o At the conclusion of 48 hours of pumping, the pump will be shut down and water level recovery in each well will be monitored for 12 hours.

- o Following a period for aquifer stabilization, the pump will be placed in the 'deeper' aquifer and the test repeated.

- o During both tests, all water discharged from the pumping wells will be collected in tank trucks, tested for contaminants, and discharged to the appropriate treatment system. It is assumed that this will be either the sanitary or industrial treatment facility.

- <u>Aquifer Test Evaluation</u>

At the conclusion of the aquifer tests, Radian will evaluate the data collected in order to determine aquifer properties. Data collected during the test will include:

- o Time vs. drawdown data for the pumping well, zone,

- o Time vs. drawdown data for observation wells in adjacent zones,

- o Pumping rate, and

- o Water discharge parameters including temperature, pH, and conductivity.

These data will be analyzed to solve for aquifer parameters including:

- o Transmissivity (T) - the rate at which water will flow through a vertical strip of an aquifer of unit width, under a hydraulic gradient of one.

- o Coefficient of Storage (S) - the volume of water released from storage per unit surface area, per unit change in head.

- o Leakage Factor - a measure of the amount of leakage into a semi-confined aquifer, from adjacent aquifers, under pumping conditions.

- o Anisotropy - variability of T and S in different horizontal directions.

Solution for these parameters will provide an understanding of the hydrologic system and will provide numeric input for modeling tasks. The actual solution methods to be used will be selected based on system response. These methods may include steady-state or non-steady-state solutions for unconfined, confined, or leaky aquifer conditions.

- <u>Acquisition of Monitoring Well Access</u>

As part of the Phase II-Stage 2 activities, monitoring wells will be installed in areas near McClellan AFB. In order to assure that the monitoring wells will remain available for long-term monitoring (30 year monitoring plan) it will be necessary to obtain permanent access right-of-ways to any wells which must be placed on private property. It is not considered adequate to simply receive approval by land owners. Accesses to private property must become part of the property deed thereby assuring permanent access even if the property is sold.

An alternative to placing wells on private property is to place wells on existing right-of-ways. While utility right-of-ways are not usually appropriate locations for wells, road right-of-ways may often be utilized. Of the 30 wells proposed for the first phase of installation it is estimated that 15 of the wells will have to be located on private property with the remainder being located on existing right-of-ways.

For wells located on existing right-of-ways, Radian personnel will prepare permit applications and submit the applications to appropriate agencies/municipalities. For wells located on private property, Radian will obtain the services of an attorney specializing in real estate law to prepare an "Agreement to Easement" document and to be available for answering questions from property owners. Radian personnel will interface with property owners to obtain their approval of the Agreement to Easement.

This "Agreement to Easement" is a voluntary agreement by the property owner to allow an easement to be placed on the property. This agreement is binding if the property is sold but, if the property is repossessed by a lender who had a lien against the property prior to the agreement to easement, the easement is voided. While this situation can be avoided by negotiating with existing holders of liens, and probably obtaining certain title insurances, Radian believes that this action will

probably not be cost-effective. Therefore, should easement be voided by foreclosure, it will be necessary to negotiate a new agreement to easement with the organization taking possession.

Two other situations may occur while attempting to obtain property easment:

- o Property owner(s) may request monetary compensation in exchange for the easement rights. Should this occur it will be the responsibility of the Air Force to negotiate and pay this compensation.

- o Property owner(s) may refuse easement rights, even if compensated. If it is deemed imperative that a well be placed on such property, access probably can be obtained through legal channels or by agency action. Because most residents have been cooperative to date, this situation is not expected to occur at most well sites. If such a situation does occur it will be the responsibility of the Air Force, in conjunction with legal processes or agencies, to obtain property easements.

- <u>Monitoring Well Installation - First Phase</u>

Under Delivery Order 16 (F33615-83-D-4001) Radian selected locations for 30 off-base monitoring wells. These locations, shown on Figure 2-4, were selected based on existing data and new information collected by Radian during Stage 2-1 activities. The proposed monitoring wells will be completed to various depths depending on local hydrogeology

and contaminant pathways. This will require the use of different drilling methods. For all monitoring wells to be completed in the unconfined (uppermost) aquifer, large diameter hollow-stem auger drilling will be utilized. The following procedure will be used:

- o A 12 inch diameter hole will be drilled with the hollow-stem auger equipment.

- o Soil samples will be collected on 5 ft. intervals from 80 ft. BLS to the water table using either split-spoon or Shelby tube samplers.

- o When ground water is encountered, soil samples will be collected at 2 1/2 ft. intervals through the aquifer.

- o After identifying the saturated zones, a 4 inch diameter, 10 foot long, stainless steel screen will be emplaced with a 10 ft. stainless-steel casing (4" diameter) above the screen, and PVC casing from the stainless casing section to the surface.

- o A clean sand or gravel pack will be emplaced around the screen.

- o A bentonite seal (if necessary) will be emplaced on top of the sand pack and cement grout will be used to seal the annulus from the bentonite seal to the land surface.

- o The placement of the sand pack, bentonite seal, and cement grout will be accomplished through the hollow-stem augers. The augers will be raised after emplacement of each item so as to ensure a bottom-to-top seal.

- After filling the annulus with grout and extracting the augers, the well head wll be completed with a protective casing and locking cap.

For deeper monitoring wells, and for shallow monitoring wells where hollow-stem drilling was ineffective, air rotary drilling with casing-drive capabilities will be utilized. This method drives a steel casing into the hole as it is drilled preventing collapse of the hole walls, especially in saturated zones. Because geologic materials and saturated zones are easily identified from drilling returns, no down-hole soil samples will be collected during drilling.

Once drilled to total depth, the monitoring well will be completed as described for shallow wells and the casing driven during drilling, will be extracted. The only difference in well construction will be that the stainless steel casing above the well screen will extend to a point above the static water level.

Following completion of each well, the well will be developed to provide maximum yield and sand-free conditions. This will aid in purging wells for later sampling. Development of the wells will be accomplished using a submersible pump and/or bottom-fill bailer.

Following development of each monitoring well, and after allowing water levels to recover, each well will be tested by pumping at a constant rate while measuring water level drawdown in the well. This procedure will provide estimations of aquifer parameters which will be input for aquifer modeling and will also provide an estimation of the maximum rate at which water can be extracted from the well. Because monitoring wells may be utilized as pumping wells in future remedial actions, it is important to know the capacity for pumping in each well.

- On-base Monitoring Well Evaluation and Redevelopment

In order to establish a comprehensive and reliable ground-water monitoring system for McClellan AFB, it will be necessary to sample both on-base and off-base monitoring wells. Radian will be installing new monitoring wells off-base and over 60 monitoring wells currently exist on base. A review of existing information, combined with new information regarding ground-water flow, geology, and most recent monitor well sampling indicates that some of the on-base wells may be inappropriately located or improperly constructed to serve as valid sampling points.

Under this task, Radian will evaluate available information and, if necessary, obtain well samples to determine which on-base monitoring wells will be useful as sampling points in establishing the ground-water program at McClellan AFB. For all wells determined to be useful (estimated to be 30 wells) Radian will redevelop the wells in an attempt to provide better sediment-free conditions and yields than exist at this time. This redevelopment will provide easier sampling conditions and longer well life than the present conditions of the wells.

Redevelopment will be performed by purging, with a low rate submersible pump. It may be necessary to add water to some wells to provide a 'surging' action. If this is necessary, the water added will be clean, potable water and, upon development, a volume equal to at least 3 times the volume added will be extracted.

- Sampling System Implementation

Upon completion of the first phase of monitoring well installation in the off-base area, and the redevelopment of appropriate on-base

monitoring wells, Radian will implement a ground-water sampling system. As part of Stage 2-1 of the McClellan IRP, Radian evaluated various potential sampling systems and selected the best well-dedicated and portable sampling systems. The two systems are discussed below.

Well-Dedicated System

The most viable well-dedicated system (sampling devices installed in each well) utilizes bladder pumps such as those supplied by Well Wizard or equivalent equipment. Bladder pumps operate by expanding and contracting a flexible tube (bladder) using compressed air. Water is brought into the pump when the bladder is deflated and purged from the pump as the bladder expands. Check valves at the pump intake and discharge control the direction of flow. The dedicated system requires that a compressed air supply be brought to each well-head along with the control unit which regulates the pressure surges to the pump.

The system's strengths lie in its ease of operation and low labor requirements. The weakness of the system is a higher initial cost than portable sampling systems.

Portable Sampling System

The most appropriate portable sampling system is a reel-mounted reciprocating piston pump, as supplied by "Bennett", or equivalent system. Reciprocating piston pumps are also air driven and would require a compressed air supply.

The advantages of this system are a lower inital cost and system flexibility. The portable system, however, requires more manpower and has a higher potential for cross-contamination.

Based on cost-effectiveness evaluation, Radian recommends that a combination of the two systems be implemented. Under this plan, all wells completed only in the uppermost saturated zone (unconfined aquifer) will be sampled using a portable pump to purge the wells and a Teflon bailer to obtain the sample.

Deeper monitoring wells will be outfitted with dedicated pumps with packers above the screened zone. The packer seals the well and isolates the screened interval. This greatly reduces the time required to purge 3-5 well volumes because only the volume within the screened interval must be pumped. It is assumed that 70 wells will be considered °shallow' and 30 wells will be considered 'deep'.

It is important to note that while the above sampling approach may provide the most cost-effective solution, based on a combination of initial costs, operation and maintenance, and labor requirements, it does not provide the lowest labor requirements. A system of all dedicated pumps (no portable pumping equipment) offers the lowest manpower requirements for sampling but has a higher initial cost. Should the Air Force determine that the lowest possible manpower requirments are more important than initial cost, it would be preferable to implement a completely well-dedicated system.

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- <u>Sampling Protocol Manual Development</u>

It is anticipated that even with the most efficient ground-water sampling system, the process of sampling the on-base and off-base monitoring wells will be a significant level-of-effort. To support this effort, Radian will prepare a sampling protocol manual which may be used to train Air Force personnel in the sampling methodology or to provide the basis for obtaining contractor services to accomplish the sampling tasks. This manual will include the following sections:

  - Location of monitoring points,
  - Description of sampling hardware,
  - Maintenance of sampling hardware,
  - Sampling protocol (detail sampling method),
  - Sample preservation and record keeping, and
  - Recommended methods of analysis.

- <u>Monitoring Well Sampling and Training</u>

Radian will conduct two rounds of monitoring well sampling for both the on-base and off-base wells. The first sampling round will occur after the first phase of off-base monitoring well installation and redevelopment of on-base monitoring wells. The second sampling round will occur after the second phase of off-base monitoring well installation and will be the first complete sampling of all wells to be included in the long-term sampling program for McClellan AFB.

For each of the two sampling rounds, Radian will provide the manpower and equipment to conduct the sampling and will provide training to Air Force personnel on the proper sampling protocol.

It is estimated that 80 wells will be included in the initial sampling round and 100 wells will be included by the second round.

- Sample Analyses

For each of the monitoring well sampling rounds, Radian will perform laboratory analysis of all samples collected. It is recommended that the following analyses be conducted:

- o pH, temperature, and conductivity, at time of sampling, and
- o EPA 601 and EPA 602 (Purgeable Organics) in the laboratory, with second column confirmation as necessary.

This provides a good coverage of organic compounds and the lowest possible detection limits. It is possible that monitoring well sampling and analysis currently in progress, and investigation of base disposal sites (planned) will reveal that additional analyses may be warranted.

All samples collected for EPA 601 and EPA 602 analyses will be placed in VOA vials and chilled until analyzed. Appropriate labelling and chain-of-custody handling will be utilized.

- Flow Model Implementation

The approach to ground-water modeling at McClellan AFB has been divided into discrete steps. These steps are:

- Conceptual Model - Development of a conceptualization of the hydrogeologic system which is necessary to begin computer modeling activities.

- Flow Model - First stage of computer modeling. A numeric model which depicts ground water flow (water levels).

- Solute Transport Model - Essentially a flow model which includes terms to account for movement of contaminants.

The conceptual model is currently being developed, based on existing information and data from Stage 2-1 activities, and will always be in a state of modification as new information becomes available.

Following aquifer testing, installation of the first phase of monitoring wells, redevelopment of on-base monitoring wells, and the first round of sampling, the flow model task will be implemented. After implementing, and calibrating the model, it will be critically reviewed for validity. If the flow model does not display valid results, development of a solute transport model will be impossible.

- Monitoring Well Siting - Second Phase

Following the installation of the first phase of monitoring wells, redevelopment of base monitoring wells, installation of sampling equipment, one round of sampling and analysis, and implementation of the flow model, Radian will review all pertinent information and select locations for the second phase of monitoring wells. It is assumed that 20 monitoring well locations will be selected in the second phase. These locations will be presented to the Air Force, along with the reasoning for each site selection, prior to the initiation of drilling activities.

- Monitoring Well-Installation - Second Phase

The second phase of monitoring well installation is anticipated to include 20 wells. The wells will be drilled by the same methods described in Section 2.5. The well construction details, development, and testing will also be the same as described in Section 2.5, assuming that 10 wells will be 'shallow' wells and 10 will be 'deep' wells.

It may also be necessary to obtain easements on private property as described in Section 2.4. It is assumed that ten of the final 20 wells will require easements.

- Well Abandonment

The well inventory and data review tasks conducted during Stag 2-1 identified several wells, both on-base and off-base, that may have been abandoned in an improper manner. It is recommended that these potential contaminant pathways be inspected and, if necessary, abandoned in an appropriate manner.

- Database Maintenance

Radian has compiled a large database (both computer and hardcopy) regarding the environmental setting of McClellan AFB and vincinity. While this database will be very useful in future activities, it will be necessary to maintain the database by continually updating and adding new data.

- Base Environmental Activity Coordination

During the next 1 to 2 years there will be great deal of environmental activity both on-base and off-base. Many of the activities are closely related and will require a coordinated effort in order to be implemented efficiently. It is recommended that a committee be established

to coordinate these efforts, or if such a committee already exists, that the principal environmental contractors be included as part of that forum. This will tend to eliminate duplications of effort and unnecessary expenditures.

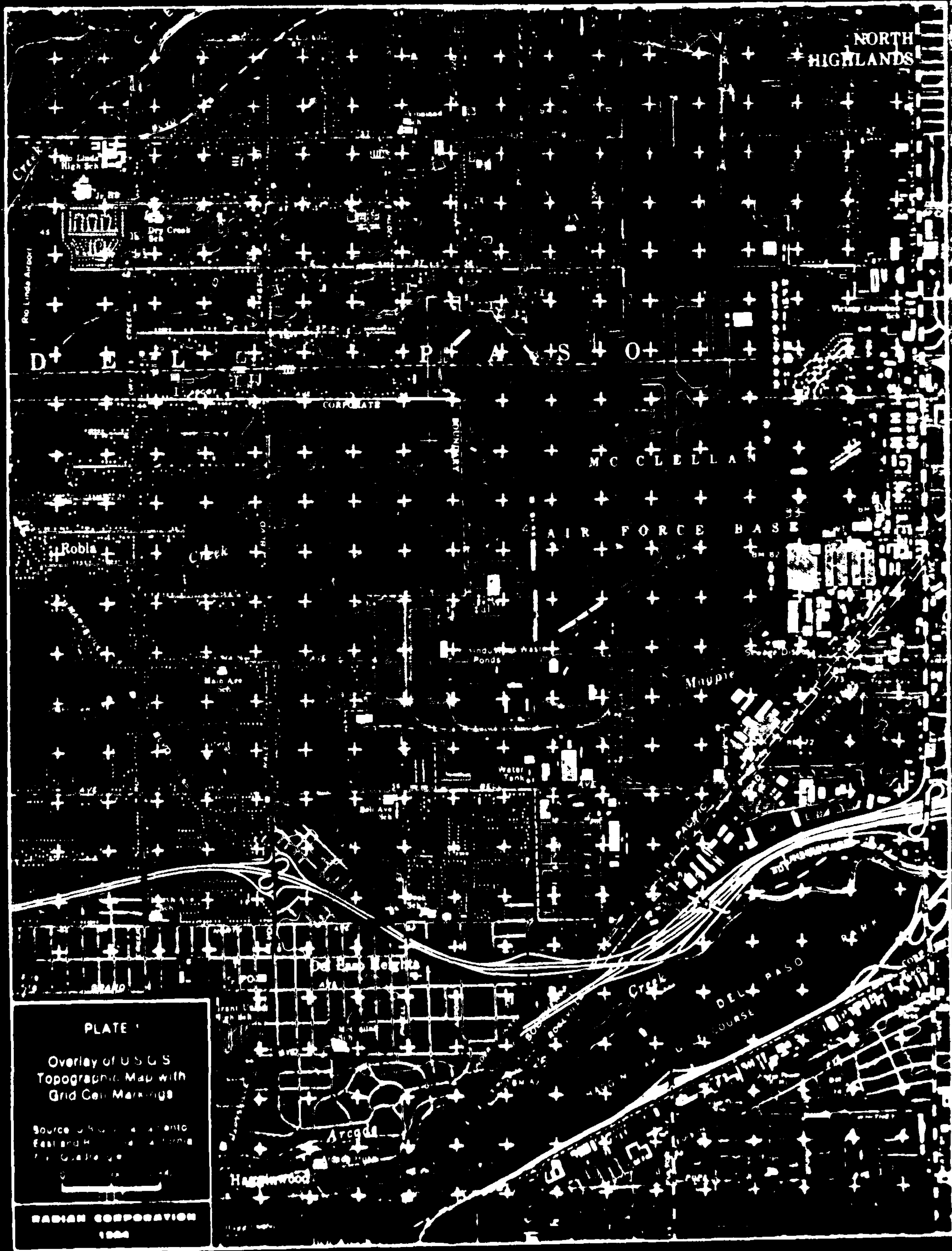
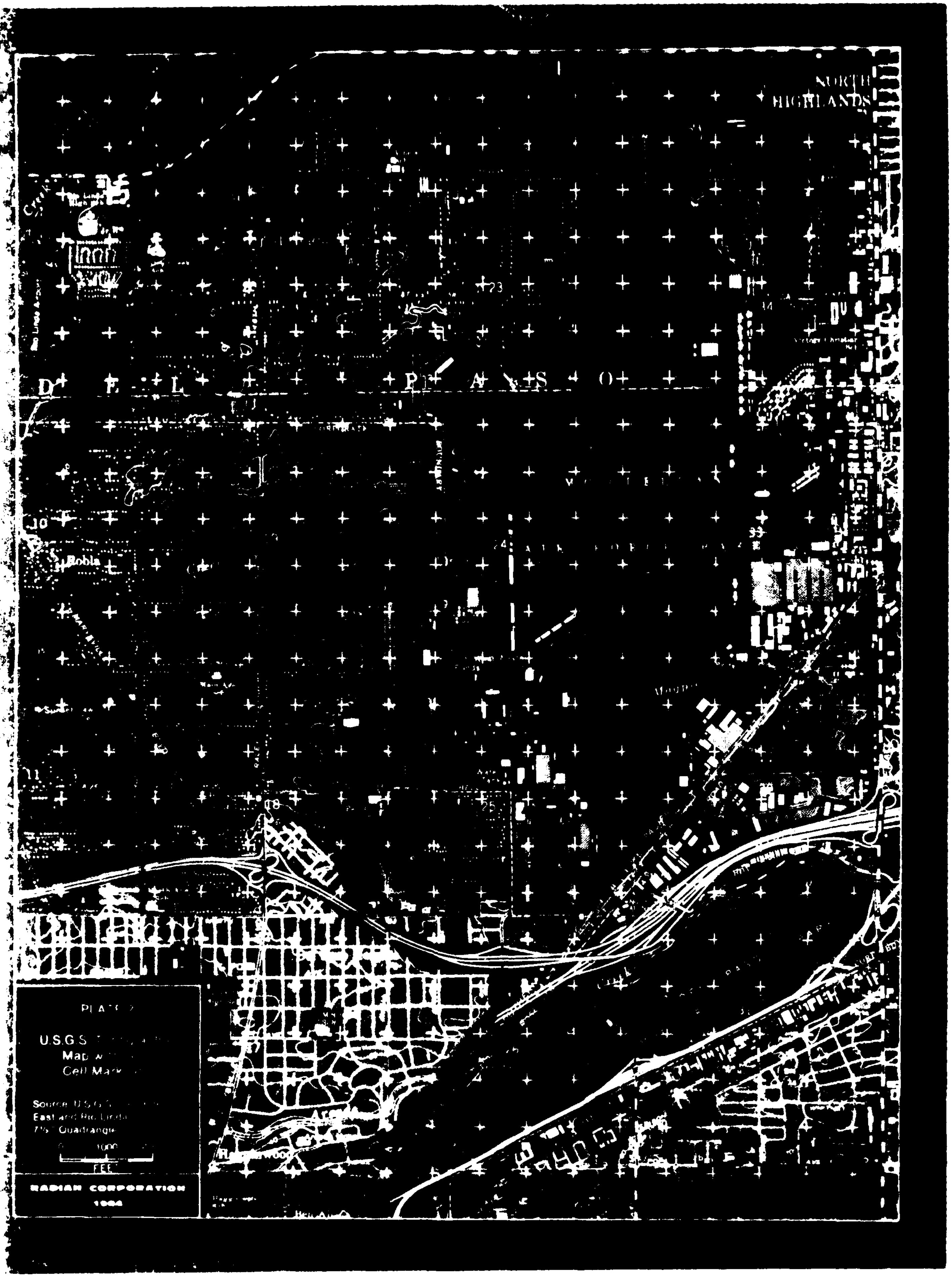


PLATE 1
Overlay of U S G S Topographic Map with Grid Cell Markings



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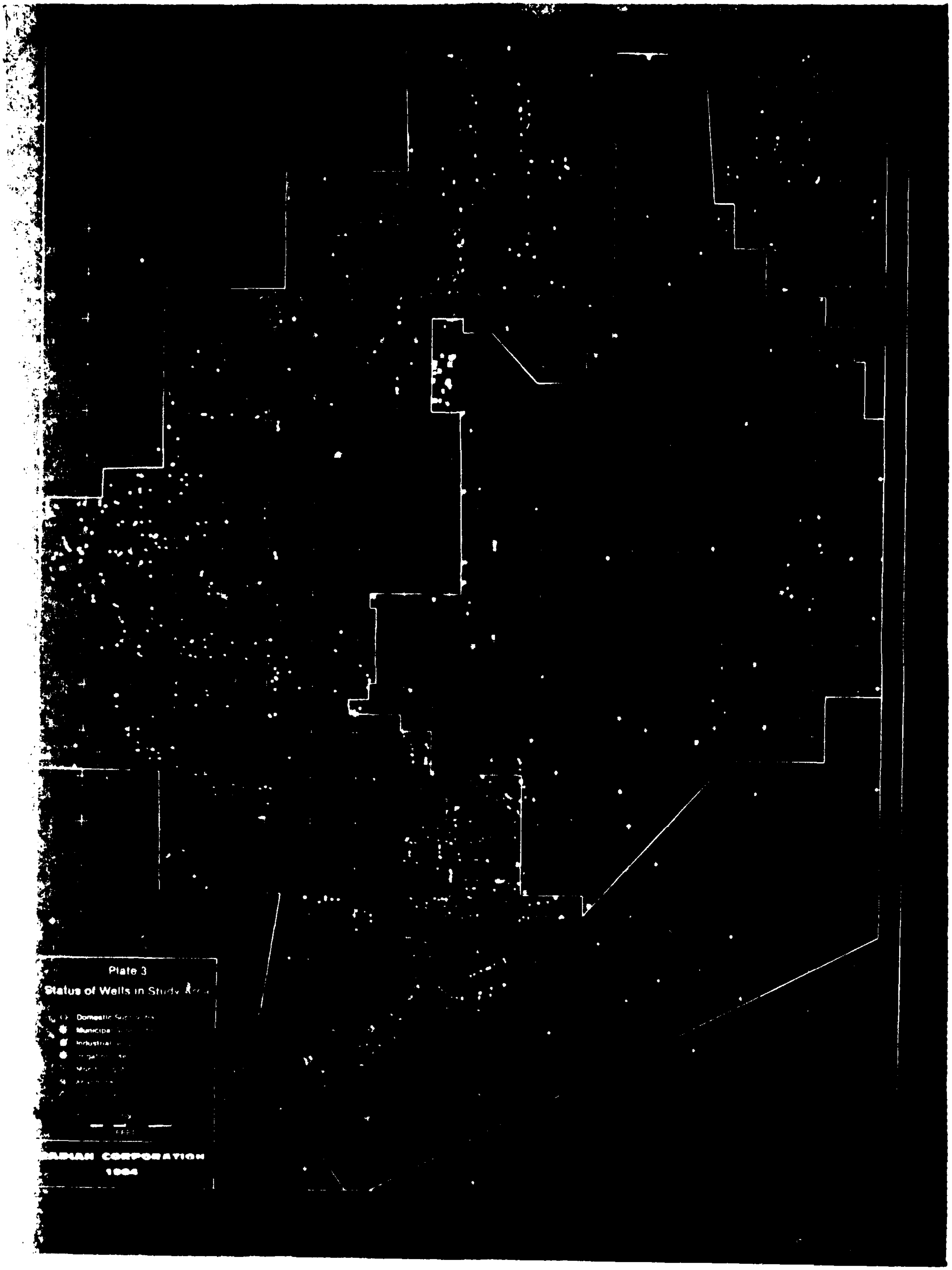
Plate 3
Status of Wells in Study
Domestic
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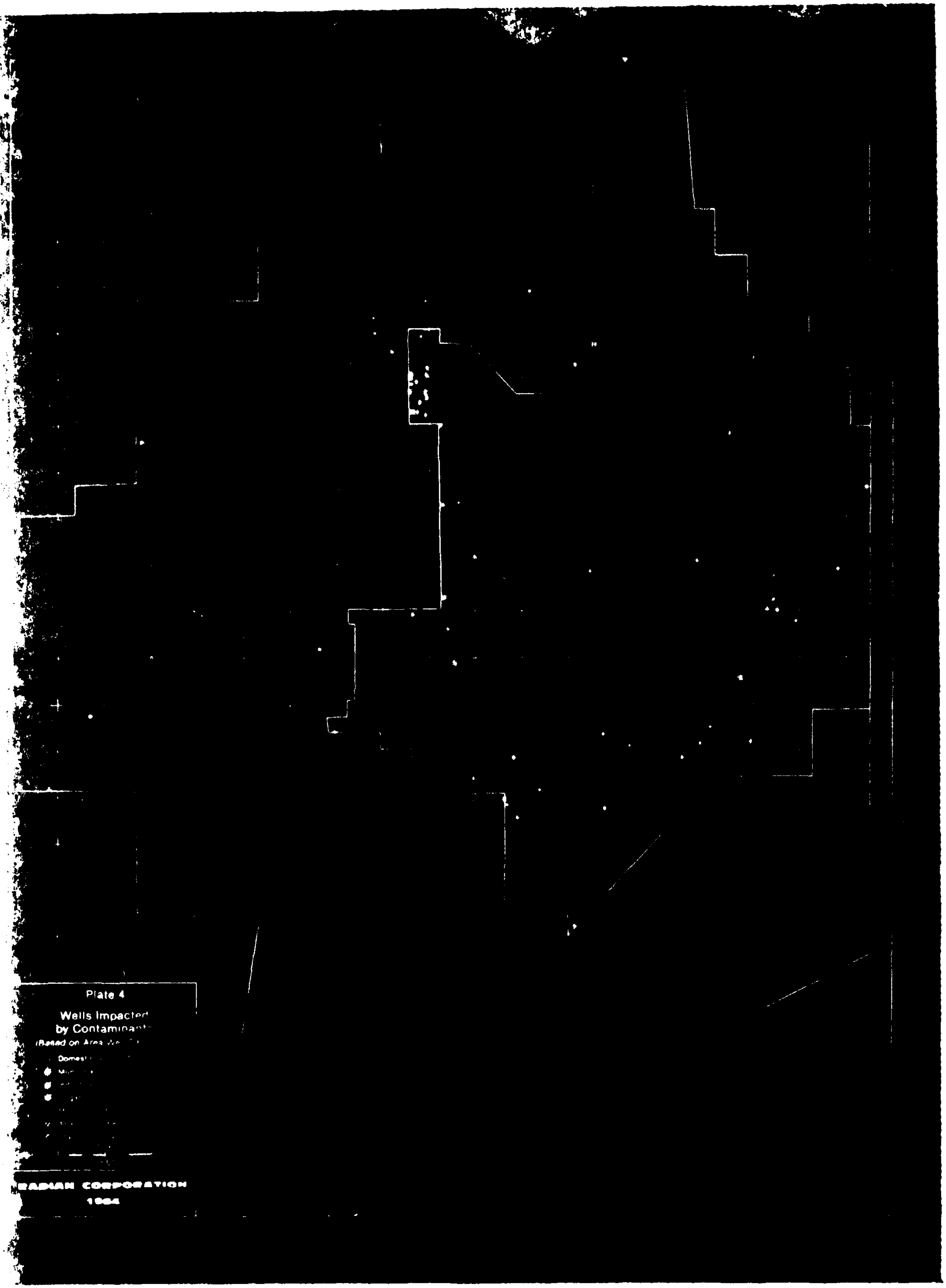
Plate 4
RADIAN CORPORATION
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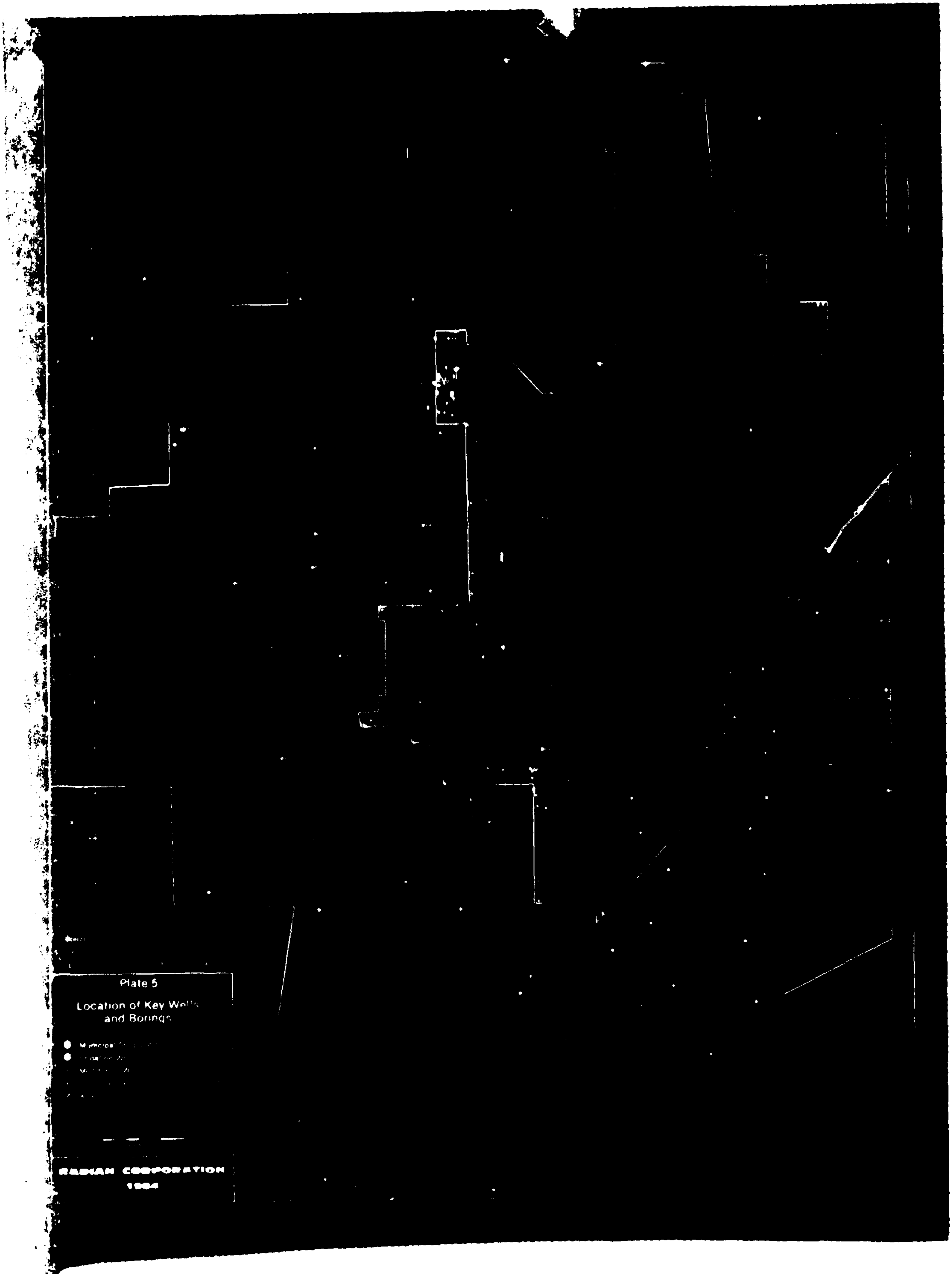
Plate 5
Location of Key Wells and Borings
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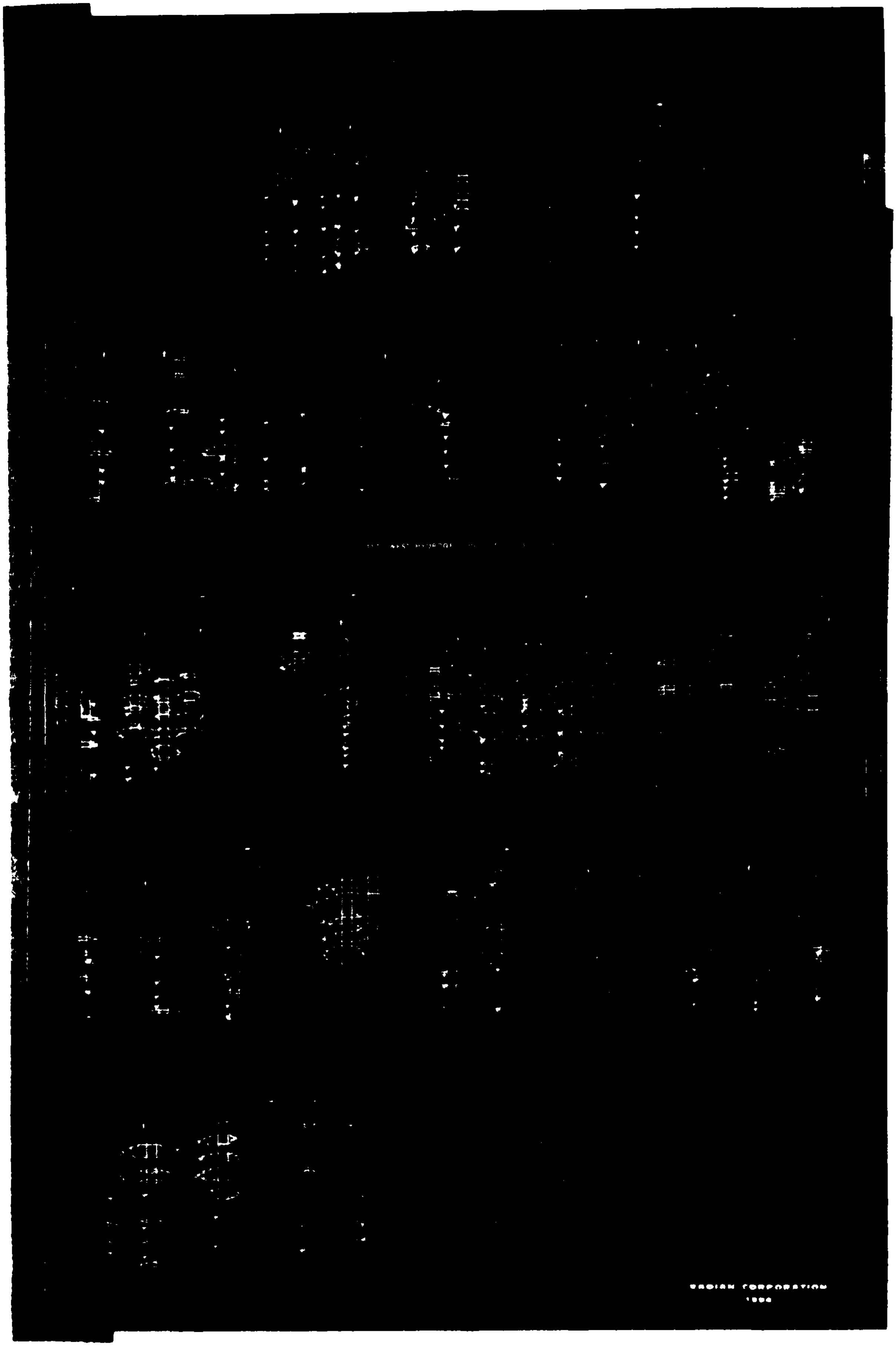
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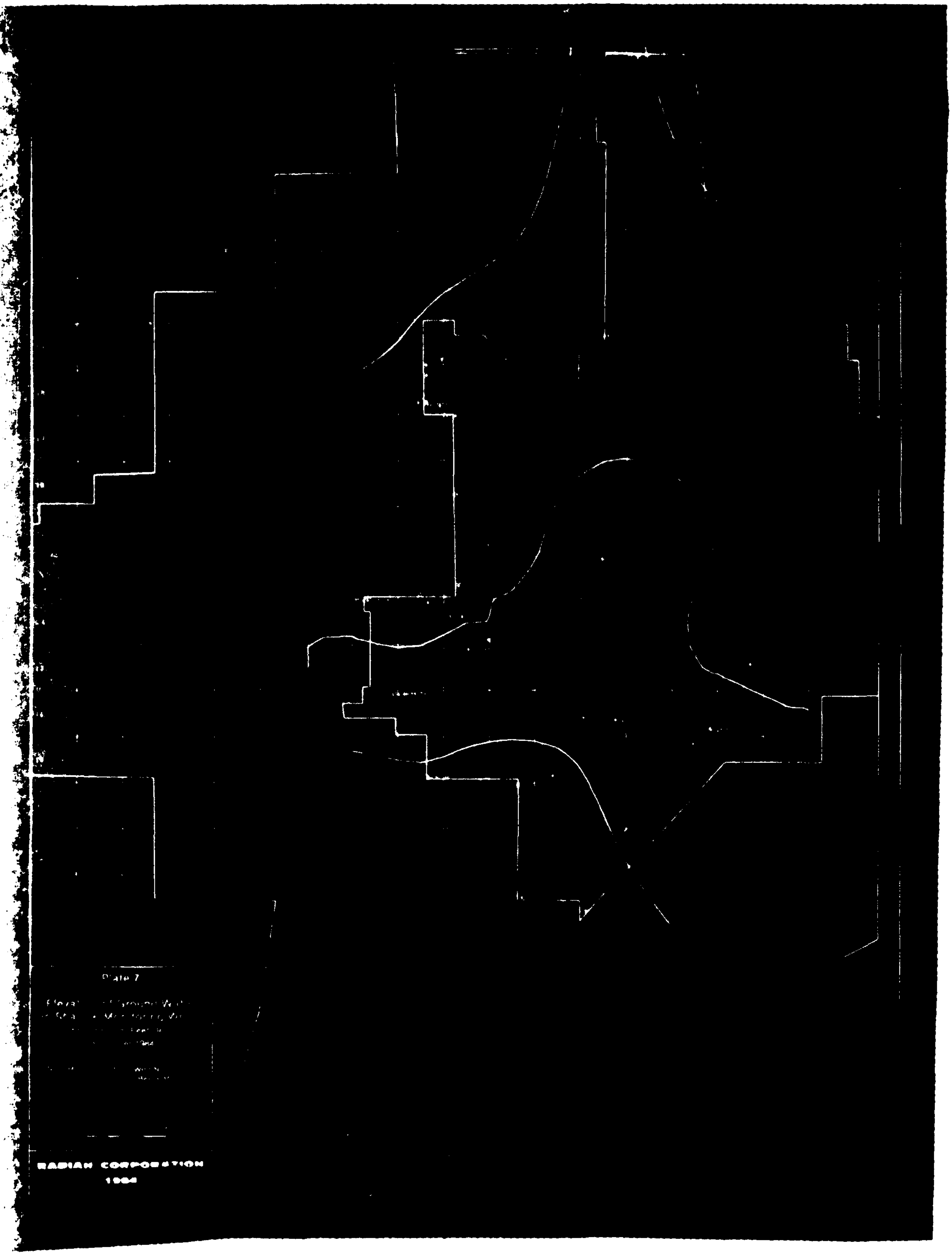
Plate 7
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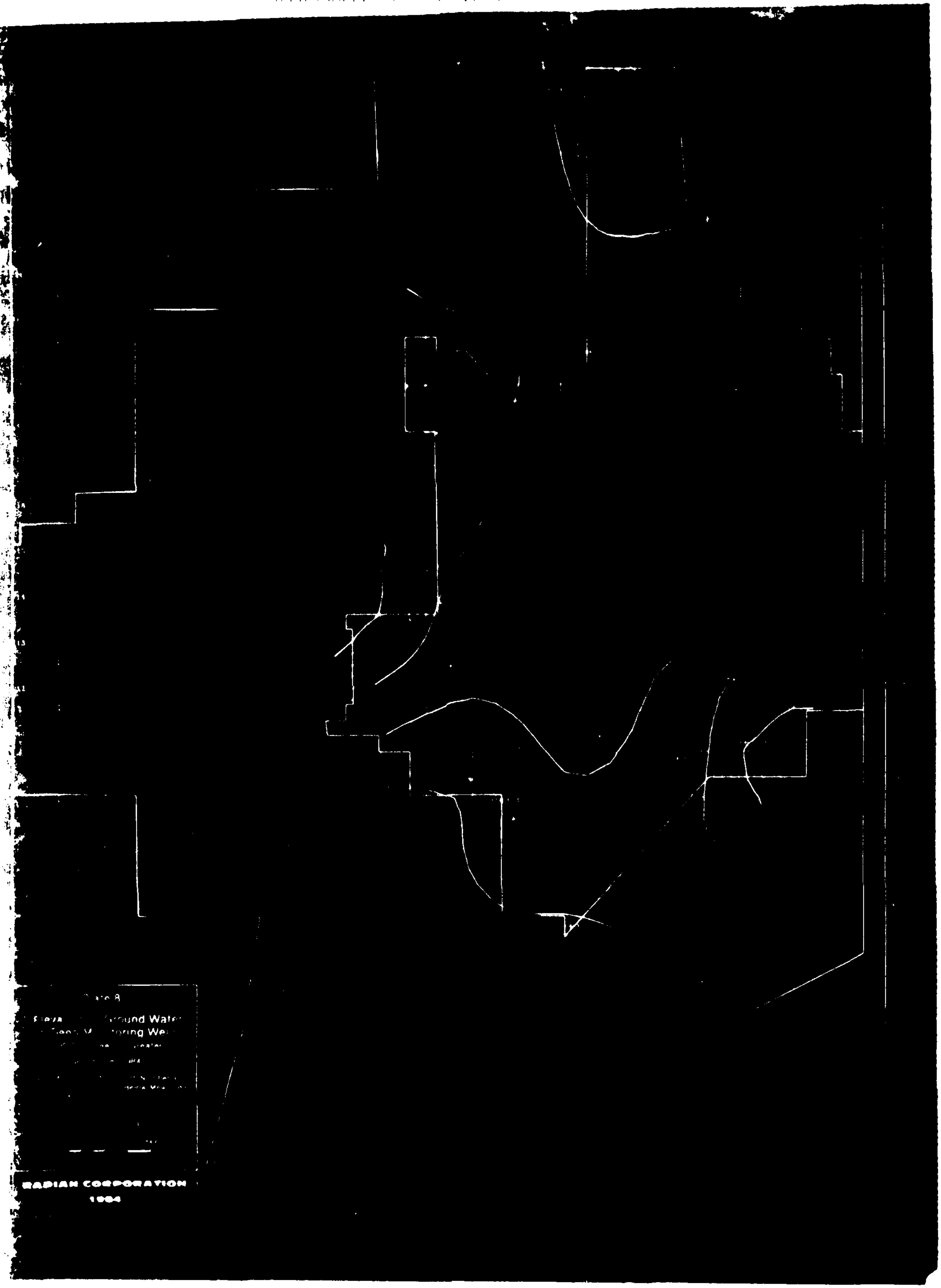
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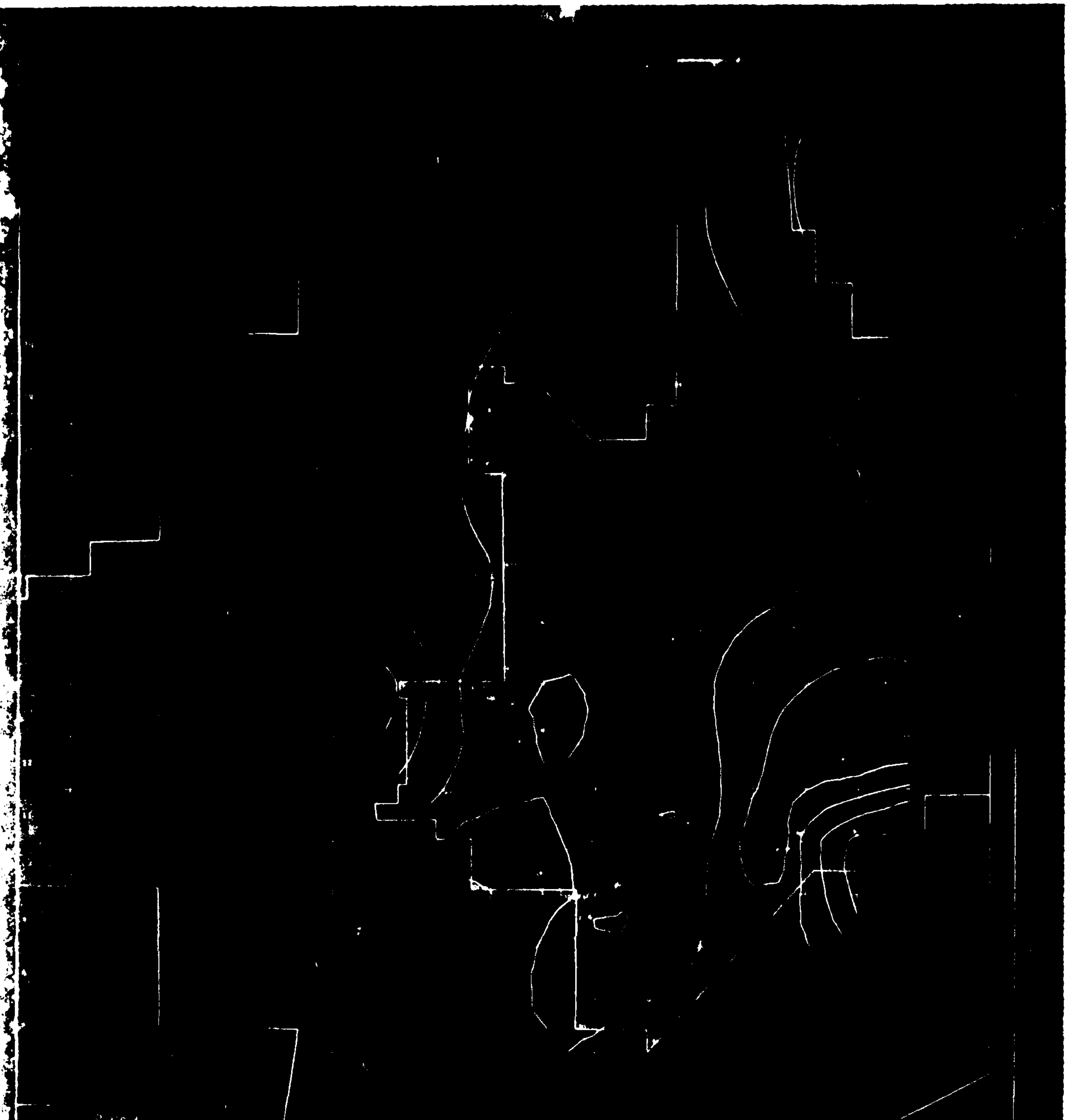

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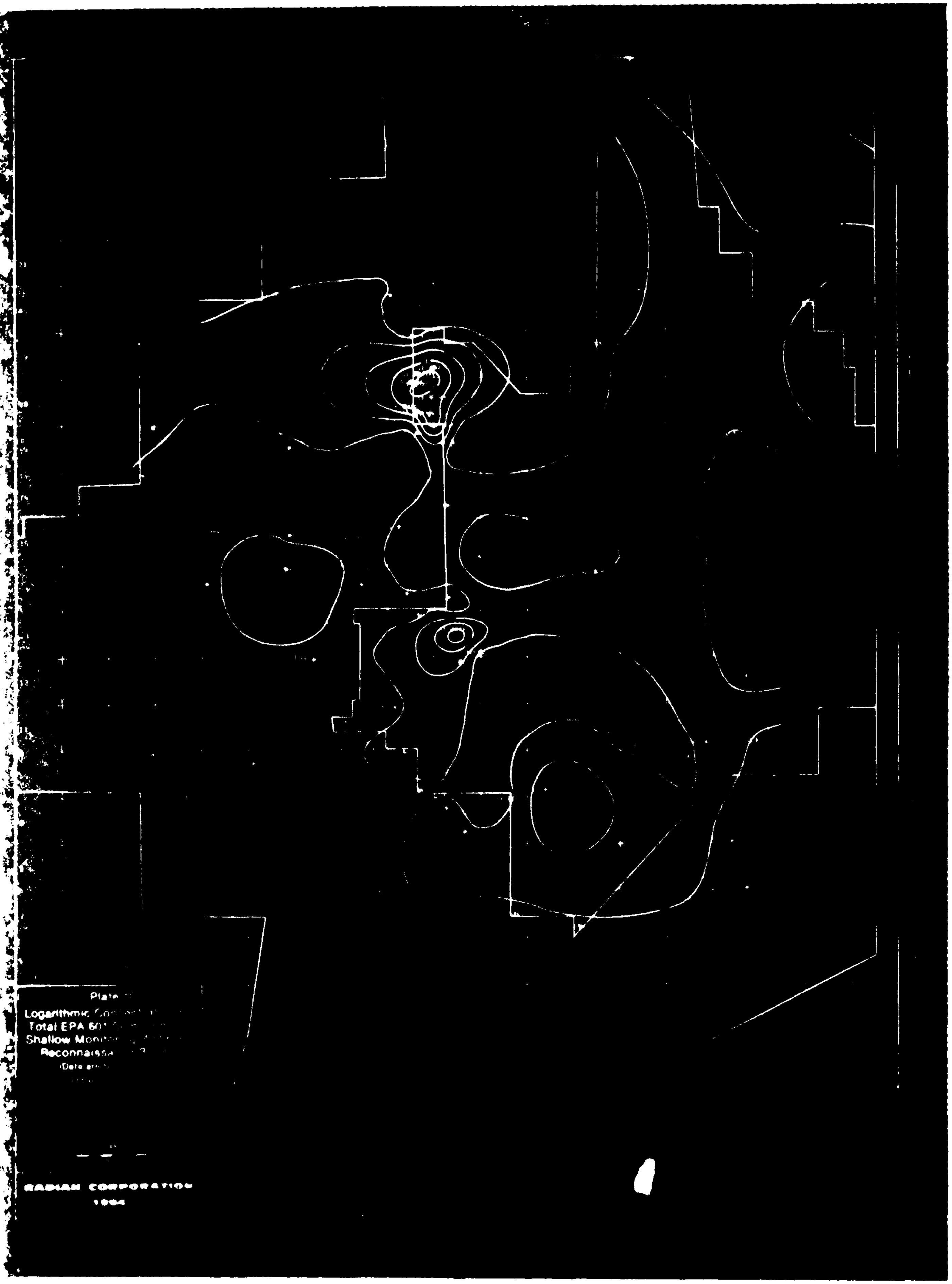
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